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OF THE

GEOLOGICAL SOCIETY.

EDITED BY

THE ASSISTANT-SECRETARY.

With Fifteen Plates, illustrating Papers by Messrs. Jukes-Browne & Hill, Dr. Woodward, Mr. P. Lake, Mr. C. W. Andrews, Dr. Hicks, Prof. T. W. E. David, Mr. Alfred Harker, and Sir Archibald Geikie.

LONDON:

LONGMANS, GREEN, AND CO.

PARIS:—FRIED. KLINCKSIECK, 11 RUE DE LILLE; F. SAVY, 77 BOULEVARD ST. GERMAIN. LEIPZIG:—T. O. WEIGEL.

SOLD ALSO AT THE APARTMENTS OF THE SOCIETY.

Price Five Shillings.

January 8th, 1896.

Dr. HENRY WOODWARD, F.R.S., President, in the Chair.

George William Colenutt, Esq., Hanway Lodge, Belvedere Street, Ryde; and John Collett Moulden, Esq., A.R.S.M., College Park, Adelaide, South Australia, were elected Fellows of the Society.

The following Fellows, nominated by the Council, were elected Auditors of the Society's accounts for the preceding year:—BENNETT H. BROUGH, Esq., and R. S. HERRIES, Esq.

The List of Donations to the Library was read.

The following communications were read:—

1. 'A Delimitation of the Cenomanian, being a Comparison of the Corresponding Beds in Southern England and Western France.' By A. J. Jukes-Browne, Esq., B.A., F.G.S., and William Hill, Esq., F.G.S.

2. 'The Llandovery and Associated Rocks of Conway.' By G. L. Elles and E. M. R. Wood, Newnham College. (Communicated by J. E. Marr, Esq., M.A., F.R.S., Sec.G.S.)

3. 'The Gypsum Deposits of Nottinghamshire and Derbyshire.' By A. T. Metcalfe, Esq., F.G.S.

The following specimens were exhibited:—

Fossils, rock-specimens, and microscope-sections, exhibited by A. J. Jukes-Browne, Esq., B.A., F.G.S., and William Hill, Esq., F.G.S., in illustration of their paper.

January 22nd, 1896.

Dr. HENRY WOODWARD, F.R.S., President, in the Chair.

Harry Graves, Esq., B.A. Oxon., 5 St. Oswald's Road, West Kensington, W.; A. W. Rogers, Esq., B.A., Christ's College, Cambridge; Alfred John Saise, Esq., C.E., Ventnor House, Fishponds, Bristol; and Lionel Leigh Smith, Esq., B.A. Cantab., Crowham Manor, Westfield, Battle, Sussex, were elected Fellows of the Society.

The List of Donations to the Library was read.

Mr. W. W. Watts, in the absence of Prof. Lapworth, called attention to three specimens of sandstone and limestone containing specimens of some species of *Hyolithes*, which Prof. Lapworth had found in the higher part of the Cambrian quartzite at Nuneaton, in Warwickshire. Three of the species recognized (*Hyolithes princeps*, *Coleoloides typicalis*, and *Stenotheca rugosa*) occur in the *Olenellus*-beds of America, and three others, *Torrellella lævigata*, *Hyolithes* (*Orthotheca*) *corneolus*, and *H. de Geeri*, in the same rocks in Europe. The *Olenellus*-zone of Nuneaton occurs above the main mass of the quartzite and below the Stockingford Shales, in a series of rocks only recently exposed by quarrying.

The following communications were read:—

1. 'On the Speeton Series in Yorkshire and Lincolnshire.' By G. W. Lamplugh, Esq., F.G.S.

2. 'On some Podophthalmatous Crustacea from the Cretaceous Formation of Vancouver and Queen Charlotte Islands.' By Henry Woodward, LL.D., F.R.S., P.G.S.

3. 'On a fossil Octopus, *Calais Newboldii* (J. de C. Sby., MS.), from the Cretaceous of the Lebanon.' By Henry Woodward, LL.D., F.R.S., P.G.S.

4. 'On Transported Boulder Clay.' By the Rev. Edwin Hill, M.A., F.G.S.

The following specimens were exhibited:—

Fossils from the Speeton Series in Yorkshire and Lincolnshire, with a microscope-section of a so-called 'derivative pebble' from the nodular bed at the base of the Spilsby Sandstone, exhibited by G. W. Lamplugh, Esq., F.G.S., in illustration of his paper.

Specimens of *Callianassa Whiteavesii*, *Homalopsis Richardsoni*, and *Plagiolophus vancouverensis*, from the Geological Survey of Canada, with two of the latter from the Society's Museum, exhibited by Dr. Henry Woodward, F.R.S., P.G.S., in illustration of his first paper.

A specimen of *Calais Newboldii*, from the Cretaceous of the Lebanon, from the Society's Museum, exhibited by Dr. Henry Woodward, F.R.S., P.G.S., in illustration of his second paper.

Specimens of *Hyolithes*-sandstone (*Olenellus*-zone) recently discovered at Nuneaton, exhibited by Prof. Charles Lapworth, LL.D., F.R.S., F.G.S.

February 5th, 1896.

Dr. Henry Woodward, F.R.S., President, in the Chair.

Colonel Charles Kendal Bushe, Bramhope, Blackheath Road, Old Charlton, Kent, and John Turner, Esq., Donisthorpe, Ashby-de-la-Zouch, were elected Fellows of the Society.

The List of Donations to the Library was read.

The following communications were read:—

1. 'On the Morte Slates and Associated Beds in North Devon and West Somerset.—Part I.' By Henry Hicks, M.D., F.R.S., F.G.S.

2. 'Evidences of Glacial Action in Australia in Permo-Carboniferous Time.' By Prof. T. W. Edgeworth David, B.A., F.G.S.

The following specimens, maps, and photographs were exhibited:—

Fossils exhibited by Dr. Henry Hicks, F.R.S., F.G.S., in illustration of his paper.

Fossils from North Devon, exhibited by the Rev. H. H. Winwood, M.A., F.G.S.; and specimens of Graptolites, exhibited by John Hopkinson, Esq., F.G.S., in illustration of Dr. Hicks's paper.

Glaciated boulders, and photographs of the same, exhibited by Prof. T. W. Edgeworth David, B.A., F.G.S., in illustration of his paper.

Fragment of Boulder from the Carboniferous Boulder Bed of the Panjáb Salt-Range, collected by Dr. H. Warth, exhibited by Dr. W. T. Blanford, F.R.S., Treas.G.S.

Australian auriferous specimens, exhibited by the President on behalf of J. C. F. Johnson, Esq., of South Australia.

Sheets 20, 21, 26, and 27 of the 1-inch Map with MS. geological work by W. A. E. Ussher, Esq., F.G.S., exhibited by the Director-General of H.M. Geological Survey.

Photograph of the late Martin Simpson, presented by Arthur Smith Woodward, Esq., F.L.S., F.G.S.

ANNUAL GENERAL MEETING,

February 21st, 1896.

Dr. HENRY WOODWARD, F.R.S., President, in the Chair.

REPORT OF THE COUNCIL FOR 1895.

THE continued prosperity of the Society from the financial point of view must again form a subject of congratulation, and the Council have the additional pleasure of pointing out that the decrease which had been noticeable in the number of Fellows, mentioned in the three previous Annual Reports, has now been all but arrested, the actual decrease in the total number of Fellows announced this year being only 1, as compared with 11 in 1894, and 46 in 1893.

During 1895 the total number of Fellows elected into the Society was 43, of whom 32 paid their fees before the end of that year. Moreover, fees were received from 12 previously elected Fellows, and thus the total accession of new Fellows amounts to 44 during the twelvemonth.

There was, on the other hand, a total loss of 45 Fellows during the year 1895—25 by death, 10 by resignation, and 10 removed from the list because of non-payment of their Annual Contributions.

The actual decrease in the total number of Fellows is, therefore, as above stated, 1.

Of the 25 Fellows deceased, 9 were Compounders, 10 were Contributing Fellows, and 6 were non-Contributing Fellows.

On the other hand, 9 Fellows compounded during the past year for their Annual Contributions. The total accession of Contributing Fellows is thus seen to be 35, and the total loss being 30 (10+10+10), the increase in the number of Contributing Fellows is 5.

At the end of 1894 the Council reported one vacancy in the List of Foreign Correspondents. In 1895, 4 Foreign Members and 1 Foreign Correspondent died. The vacancies which thus arose were partly filled by the election of 3 Foreign Members and 3 Foreign

Correspondents during the past year: but at the end of 1895 there was still 1 vacancy in the List of Foreign Members, and 2 vacancies in the List of Foreign Correspondents.

The total number of Fellows, Foreign Members, and Foreign Correspondents, which at the end of 1894 was 1321, stood at 1318 on December 31st, 1895.

The Society's Income and Expenditure in the year under review may be summarized as follows:—

The total Receipts amounted to £3249 13*s.* 4*d.*, being £666 7*s.* more than the estimated Income for 1895. On the other hand, the total Expenditure during that year amounted to £2398 5*s.* 11*d.*, being less by £181 10*s.* 1*d.* than the estimated Expenditure for 1895. The actual excess of Receipts over current Expenditure in that year was £492 18*s.* 4*d.*

It should be mentioned here that the following Re-investment of a portion of the Society's Funds was made in 1895. Of $2\frac{3}{4}$ per Cent. Consolidated Stock £3769 2*s.* 6*d.* was sold at $104\frac{3}{8}$, and the sum thus produced was applied to the purchase of £2000 India 3 per Cent. Stock at 104, and £1295 Midland Railway 4 per Cent. Perpetual Preference Stock at $141\frac{1}{4}$. Moreover, in the various Trust Funds held by the Society, the following Re-investments were made. On account of the Wollaston Fund £1081 1*s.* 1*d.* $2\frac{3}{4}$ per Cent. Consolidated Stock was sold at $104\frac{5}{8}$, and the sum thus obtained was applied to the purchase of £1073 Hampshire County 3 per Cent. Stock at £$105\frac{3}{8}$. Similarly, the £500 $2\frac{3}{4}$ per Cent. Consolidated Stock belonging to the Barlow-Jameson Fund was sold at £$104\frac{5}{8}$, while £468 Great Northern Railway 3 per Cent. Debenture Stock was purchased in lieu of it at £$110\frac{3}{8}$; also £209 8*s.* 6*d.* $2\frac{3}{4}$ per Cent. Consolidated Stock forming the Bigsby Fund was sold at £$104\frac{5}{8}$, and the sum thus obtained was applied to the purchase of £210 Cardiff Corporation 3 per Cent. Stock at $104\frac{1}{2}$. It need hardly be pointed out that the object of these Re-investments was to obtain a larger Income while still holding perfectly sound securities.

The Council have pleasure in announcing the completion of Volume LI. of the Society's Quarterly Journal and the commencement of Volume LII.

The first number of the new Record of Geological Literature added to the Society's Library was issued concurrently with the May number of the Journal in 1895, and its usefulness seems to have been very generally recognized. As was stated in the previous Report of the Council, now and in future this publication will appear concurrently with the February number of the Society's Quarterly Journal.

The compilation of the Index to the first Fifty Volumes of the Quarterly Journal is now all but complete, Vol. 48 having been reached, and the manuscript will very soon be placed in the hands of the printers. It is confidently hoped that the whole of the Index will be placed in the Fellows' hands in the course of the present year.

The question as to how far it is desirable for the Society to maintain a Museum has, for a considerable time, been under the earnest consideration of the Council, and it was felt that if the Society decided that the maintenance of the collections in their present condition was undesirable, the British Museum (Natural History) would probably be the most satisfactory receptacle for them. The Council have accordingly been in communication with the Trustees of the British Museum, and find that they would be willing to receive such portions of the collections as the Society may wish to transfer to them on the following conditions :—The specimens which are types and those which illustrate papers read before the Society are to be preserved and maintained apart, and the Trustees will reimburse the Society for the expenses in connexion with the transference up to a sum not exceeding £300.

The provisional assent of the Trustees of the British Museum to these conditions was formally given at their meeting of January 25th, 1896; and as the ultimate decision regarding the proposed transference must rest with the general body of Fellows, the subject will no doubt be brought forward at a Special General Meeting at an early date.

Meanwhile, a short summary of the steps taken in connexion with the Museum may here be brought to the notice of the Fellows.

On April 22nd, 1891, the attention of the Council having been drawn by the Rev. J. F. Blake to the unsatisfactory state of the Society's Museum, as regards defective labelling, incomplete registration, bad conditions of location and preservation of specimens, etc., a Special Committee was appointed to examine into the question. On May 27th, that Committee finally reported to the effect that it was desirable to select and register all specimens illustrating the history of the Society (including type-specimens), and called attention to collections of simple minerals, typical foreign rocks, and recent shells, with a view to their possible removal. This report was adopted by the Council the same day (May 27th, 1891), and Mr. C. Davies Sherborn, F.G.S., was afterwards requested to undertake the work of registration of important specimens thus selected. This task Mr. Sherborn proceeded with as rapidly as the state of his health would allow. He completed it, so far as the English Collections were concerned, and, by the end of 1895, had gone through part of the Foreign Collection, having, in all, examined about three-fifths of the Society's Museum.

An epitome of the contents of the Museum and a statement of the work accomplished were laid before a Special Committee on October 29th, 1895, and that Committee reported on November 6th to the Council, recommending the transference of the Museum to the National Collections on the conditions already cited, reserving to the Society such specimens of historical interest or of an ornamental nature as are displayed on the walls of the Society's Apartments. This Report was, after careful consideration, adopted by the Council on November 20th, 1895.

If the Society decide upon the transference, the space, when vacated by the collections, would become available for the Library; and the Council must point out that the provision of further accommodation for books will soon become a matter of urgent necessity. As it is, the proper and commodious arrangement of many of the serial publications is hampered for want of room.

The Council are of opinion that the Redecoration of the Society's Apartments and the introduction of the Electric Light constitute improvements which it is desirable to carry out at an early date. The total cost would probably amount to between £700 and £800, and the Balance Sheet placed in the hands of the Fellows shows that the necessary expenditure could be almost entirely provided for from the surplus that has accrued during the last few years. At the same time, the expense of only a portion of the necessary Redecoration is included with that of the Electric Installation in the Estimates for the current year, so that the whole expenditure may be spread over a period of not less than two years.

The following awards of Medals and Funds have been made by the Council:—

The Wollaston Medal is awarded to Prof. Eduard Suess, For. Memb. G.S., of Vienna, in recognition of his long and brilliant services to the cause of Geological Science.

The Murchison Medal, with a sum of Ten Guineas, is awarded to Mr. T. Mellard Reade, F.G.S., in recognition of the value of his work on mountain-making, Glacial drifts, and other branches of post-Pliocene geology.

The Lyell Medal, with a sum of Twenty-five Pounds, is awarded to Mr. Arthur Smith Woodward, F.G.S., in recognition of the value of his work on Fossil Vertebrata, and especially in Palæichthyology.

The Balance of the Proceeds of the Wollaston Fund (together with a sum of Six Pounds Fifteen Shillings transferred from the Barlow-Jameson Fund, in order to supplement an accidental deficiency in the Wollaston Fund incidental to the aforementioned change of investments) is awarded to Mr. Alfred Harker, in testimony of appreciation of his petrological work, and with the view of assisting him in further research.

The Balance of the Proceeds of the Murchison Geological Fund is awarded to Mr. Philip Lake, F.G.S., as a recognition of the value of his palæontological and other researches amongst the older rocks, and to aid him in the prosecution of these studies.

A moiety of the Balance of the Proceeds of the Lyell Geological Fund is awarded to Dr. W. F. Hume, F.G.S., for his researches on Cretaceous rocks and on the Loess formation, and also to assist him in further work.

The other moiety of the Balance of the Proceeds of the Lyell Geological Fund is awarded to Mr. Charles W. Andrews, F.G.S., in recognition of the value of his work on Fossil Birds and Reptilia, and to assist him in the prosecution of further investigations.

An award of Twenty Pounds is made from the Barlow-Jameson Fund to Mr. Joseph Wright, F.G.S., in token of appreciation of his

work on the microfauna of the Irish Chalk, and with the view of aiding him in further research.

Another award of Twenty Pounds from the Barlow-Jameson Fund is made to Mr. John Storrie, of Cardiff, as a mark of appreciation of his original work on the geology of the neighbourhood of that town, and to assist him in carrying out further useful investigations.

The Council cannot conclude this Report without referring to the loss which the Society has sustained in the person of its valued and most efficient Assistant-Clerk, Mr. Francis E. Brown, who died suddenly in the beginning of August last. He had served the Society for upwards of nine years, and had earned the esteem and confidence, not only of the Officers and Council, but of all those among the Fellows who came into contact with him.

Report of the Library Committee for 1895.

Your Committee have pleasure in stating that very many valuable additions have been made to the Library during the past year, both by Donation and Purchase. It is, in a large measure, due to the liberality of the Fellows, of various public bodies, and of kindred societies, that the donations far exceed in amount the purchases: this will be readily deduced from the statistics embodied in the present Report.

By Donation the Library has received about 85 Volumes of separately published works, 377 Pamphlets and detached Parts of works, 172 Volumes and 207 detached Parts of serial publications (Transactions, Memoirs, Proceedings, etc.), and 16 Volumes of Newspapers. The total addition to the Library by Donation amounts therefore to 273 Volumes, 377 Pamphlets, and 207 detached Parts. Moreover, 116 Sheets of Maps have been presented to the Society during the past year.

Your Committee desire to call special attention to the magnificent Geologic Atlas of the United States, all the sheets of which (so far as published) have been presented by the Government of that country. Nor have other public bodies in the United States failed in their wonted liberality: among others, the New York, Minnesota Missouri, and Alabama State Geological Surveys have enriched this Society's Library with many handsome volumes of memoirs, plates, and maps. Three important volumes of the Beiträge zur geologischen Karte der Schweiz have been received from the Swiss Geological Commission during the past year, as also a large number of maps from the Geological Survey of the kingdom of Saxony. No less than twenty-four sheets of maps have been presented by the Geological Survey of Canada, and six volumes of memoirs by the Comité Géologique of St. Petersburg. From H.M. Geological Survey have come some important memoirs and several sheets of the 1-inch map (both drift and solid geology) and sheets of horizontal and vertical sections; while from H.M. Treasury the Society has received the volume embracing the Summary of the Scientific Results of the

'Challenger' Expedition. The first instalment of the International Geological Map of Europe (including seven sheets) has also been received, and from the Geological Survey of India has come the 2nd edition of the small-scale geological map of that Empire.

A valuable collection of geological papers, many of which are now out of print, has been presented by Prof. G. J. Allman, F.R.S. Monsieur P. de Loriol-Lefort, For.Corr.G.S., of Geneva, Señor Don Florentino Ameghino, of Buenos Ayres, and the Marchese A. de Gregorio, of Palermo, have respectively enriched the Library with sets of their own papers and memoirs; and the Royal University of Upsala, besides presenting the 'Meddelanden' published by its Geological Institute, has sent through its Librarian a considerable number of separately printed papers by Scandinavian geologists.

The Society's collection of portraits of historical interest has been enriched by the presentation of a drawing in crayons of Leonard Horner, given by Mrs. Katherine Lyell, and a photograph of the well-known Yorkshire geologist, Martin Simpson, given by Mr. Arthur Smith Woodward. Moreover, a portrait in oils of the late Dean Buckland has been purchased from his daughter, Mrs. Gordon.

The Books, Maps, and Portraits enumerated above were the gift of 191 Personal Donors, 62 Public Bodies, and 200 Societies and Editors of Periodicals.

The Purchases made on the recommendation of the Standing Library Committee amounted to 36 Volumes and 15 Parts of separately published works, 25 Volumes and 20 Parts of works published serially, and 10 Sheets of Maps.

The total amount expended upon the Library during the year 1895 is as follows:—

	£	s.	d.
Books, Periodicals, etc., purchased	68	7	5
Binding of Books and Mounting of Maps....	99	1	10
Part cost of preparing Map Catalogue	3	11	3
	£171	0	6

Your Committee have pleasure in announcing that the manuscript Card Catalogue of the Geological Maps and Sections in the Library is now practically completed.

As the question of the Museum has been dealt with by a Special Committee who have reported to the Council, all that need be said in this place is that the sum set apart in the Estimates, for registering and cataloguing specimens, namely £50, has been expended during the past year, and constitutes the sole item of expenditure incurred in connexion with the Museum in 1895.

The following Lists contain the Names of Government Departments, Public Bodies, Societies, Editors, and Personal Donors, from whom Donations to the Library have been received during the past year:—

I. Government Departments and other Public Bodies.

Alabama.—Geological Survey of Alabama. Montgomery (Ala.).
American Museum of Natural History. New York.
Austria.—Kaiserlich-Königliche Geologische Reichsanstalt. Vienna.
——. Kaiserlich-Königliches Naturhistorisches Hofmuseum. Vienna.
Baden.—Grossherzogliches Ministerium des Innern. Geologische Landesanstalt. Heidelberg.
Bavaria.—Königlich Bayerisches Oberbergamt. Munich.
California.—State Mining Bureau. San Francisco.
Canada.—Geological & Natural History Survey. Ottawa.
Finland.—Finlands Geologiska Undersökning. Helsingfors.
France.—Dépôt de la Marine. Paris.
——. Ministère des Travaux Publics. Paris.
——. Muséum d'Histoire Naturelle. Paris.
——. Service de la Carte Géologique. Paris.
Great Britain.—Army Medical Department. London.
——. British Museum (Natural History). London.
——. Geological Survey. London.
——. Home Office. London.
——. Ordnance Survey.
——. The Lords Commissioners of Her Majesty's Treasury. London.
Hesse.—Grossherzogliches Ministerium des Innern. Geologische Landesanstalt. Darmstadt.
Holland.—Departement van Kolonien. The Hague.
Hungary.—Königliche Ungarische Geologische Anstalt. Budapest.
Illinois.—State Museum of Natural History. Springfield (Ill.).
India.—Geological Survey. Calcutta.
Italy.—Reale Comitato Geológico d'Italia. Rome.
Japan.—Geological Survey. Tokio.
La Plata Museum. La Plata.
Mexico.—Comision Geológica de Mexico. Mexico.
Minnesota.—Geological and Natural History Survey. Minneapolis.
Missouri.—Geological Survey of Missouri. Jefferson City (Mo.).
New South Wales.—Agent-General for, London.
——. Australian Museum. Sydney.
——. Department of Lands. Sydney.
——. Department of Mines. Sydney.
——. Geological Survey. Sydney.
New York State Library. Albany.
New York State Museum. Albany.
Norway.—Norges Geologiska Undersökning. Christiania.
Nova Scotia.—Department of Mines. Halifax (N.S.).
Perak Government. Taiping.
Portugal.—Commissão Geologica de Portugal. Lisbon.
Prussia.—Königliche Preussische Geologische Landesanstalt. Berlin.
——. Königliches Ministerium für Handel und Gewerbe. Berlin.
Queensland.—Geological Survey. Brisbane.
Russia.—Comité Géologique. St. Petersburg.
Saxony.—Geologische Landesuntersuchung des Königreichs Sachsen. Leipzig.
——. Königliches Finanz-Ministerium. Leipzig.
South Australia.—The Agent-General for, London.
Spain.—Comision del Mapa Geológico. Madrid.
Sweden.—Sveriges Geologiska Undersökning. Stockholm.
Switzerland.—Commission der Geologischen Karte. Berne.
United States Bureau of Ethnology. Washington.
United States Department of the Interior. Washington.
United States 'Field' Columbian Museum. Chicago.
United States Geological Survey. Washington.
United States National Museum. Washington.

United States Treasury (Mint) Department. Washington.
Victoria.—Department of Mines. Melbourne.
Washington (D. C.).—Smithsonian Institution.
Western Australia.—Department of Mines. Perth.
——. Geological Survey. Perth.
——. The Agent-General for, London.

II. Societies and Editors.

Adelaide.—Royal Society of South Australia.
Alnwick.—Berwickshire Naturalists' Club.
Bahia.—Instituto Geographico e Historico.
Barnsley (Newcastle-upon-Tyne).—Midland Institute of Mining, Civil and Mechanical Engineers.
Basel.—Schweizerische Naturforschende Gesellschaft.
Bath Natural History and Antiquarian Field Club.
Belfast Natural History and Philosophical Society.
Belgrade.—Annales Géologiques de la Péninsule Balkanique.
Berkeley (Cal.).—Department of Geology, University of California.
Berlin.—Deutsche Geologische Gesellschaft.
——. Gesellschaft Naturforschender Freunde.
——. Königliche Preussische Akademie der Wissenschaften.
——. Zeitschrift für praktische Geologie.
Berne.—Allgemeine Schweizerische Gesellschaft für die gesammten Naturwissenschaften.
——. Naturforschende Gesellschaft.
Birmingham.—Mason College.
——. Philosophical Society.
Bombay.—Poona College of Science.
Boston (Mass.).—American Academy of Arts and Sciences.
Boston Society of Natural History.
Brussels.—Académie Royale des Sciences, des Lettres et des Beaux-Arts de Belgique.
——. Société Belge de Géologie, de Paléontologie et d'Hydrologie.
——. Société Malacologique de Belgique.
Budapest.—Földtani Közlöny (Geological Magazine).
——. Magyar Földtani Tarsulat.
Buenos Aires.—Instituto Geografico Argentino.
——. Sociedad Cientifica Argentina.
Caen.—Société Linnéenne de Normandie.
Calcutta.—Indian Engineering.
——. Asiatic Society of Bengal.
Cambridge.—University Library Syndicate.
Cambridge (Mass.).—Museum of Comparative Zoology, at Harvard College.
Cape Town.—South African Philosophical Society.
Cardiff.—South Wales Institute of Engineers.
Chicago.—Journal of Geology.
Christiania.—Videnskabernes Selskab.
Cincinnati Society of Natural History.
Colombo.—Ceylon Branch of the Royal Asiatic Society.
Colorado Springs (Col.).—Colorado College Scientific Society.
Copenhagen.—Dansk Geologisk Forening.
——. Kongelige Danske Videnskabernes Selskab.
Córdoba (Argentine Republic).—Academia Nacional de Ciencias.
Cork.—Queen's College.
Cracow.—Académie des Sciences.
——. Akademja Umiejętosci.
Darmstadt.—Verein für Erdkunde.
Dijon.—Académie des Sciences, Arts et Belles-Lettres.
Dorchester.—Dorset Natural History and Antiquarian Field Club.
Dorpat.—Naturforscher Gesellschaft bei der Universität Jurjew.
Douglas.—Isle of Man Natural History and Antiquarian Society.
Dresden.—Naturwissenschaftliche Gesellschaft 'Isis.'
Dublin.—Royal Irish Academy.
Edinburgh.—Royal Scottish Geographical Society.
——. Royal Society.

Ekaterinburg.—Société Ouralienne d'Amateurs des Sciences Naturelles.
Falmouth.—Royal Cornwall Polytechnic Society.
Frankfurt a. M.—Senckenbergische Naturforschende Gesellschaft.
Glasgow.—'Mitchell' Library.
Giessen.—Oberhessische Gesellschaft für Natur- und Heilkunde.
Glasgow.—Philosophical Society.
Gloucester.—Cotteswold Naturalists' Field-Club.
Gratz.—Naturwissenschaftlicher Verein für Steiermark.
Haarlem.—Société Hollandaise des Sciences.
Halifax.—Yorkshire Geological and Polytechnic Society.
Halifax (N. S.)—Nova Scotian Institute of Science.
Halle.—Kaiserliche Leopoldinisch-Carolinische Deutsche Akademie der Naturforscher.
Hamilton (Canada).—Hamilton Association.
Hanau.—Wetterauische Gesellschaft für die gesammte Naturkunde.
Havre.—Société Géologique de Normandie.
Hertford.—Hertfordshire Natural History Society.
Houghton (Mich.).—Michigan Mining School.
Hull.—Geological Society.
Ithaca (N. Y.).—Cornell University.
Kiev.—Société des Naturalistes.
Kingston (Canada).—Queen's College.
Lausanne.—Société Géologique Suisse.
——. Société Vaudoise des Sciences Naturelles.
Leeds.—Geological Association.
——. Philosophical Society.
Leicester Literary and Philosophical Society.
Leipzig.—Naturwissenschaftlicher Verein für Sachsen und Thüringen.
——. Zeitschrift für Krystallographie und Mineralogie.
——. Zeitschrift für Naturwissenschaften.
Liége.—Société Géologique de Belgique.
——. Société Royale des Sciences.
Lille.—Société Géologique du Nord.
Lisbon.—Academia Real das Sciencias.
——. Sociedade de Geographia.
Liverpool.—Geological Association.
——. Geological Society.
——. Naturalists' Field-Club.
London.—Academy.
——. Athenæum.
——. British Association for the Advancement of Science.
——. Chemical News.
——. Chemical Society.
——. City of London College.
——. Colliery Guardian.
——. East India Association.
——. Geological Magazine.
——. Geologists' Association.
——. Institution of Civil Engineers.
——. India Rubber, Gutta Percha, and Telegraph Works Co., Lim.
——. Iron and Steel Institute.
——. Iron and Steel Trades' Journal.
——. Knowledge.
——. Linnean Society.
——. London, Edinburgh, and Dublin Philosophical Magazine.
——. Mineralogical Society.
——. Nature.
——. Palæontographical Society.
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——. Royal Agricultural Society.
——. Royal Astronomical Society.
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——. Royal Geographical Society.
——. Royal Institution.
——. Royal Meteorological Society.
——. Royal Microscopical Society.
——. Royal Photographic Society of Great Britain.
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London.—Sanitary Institute.
——. Society of Arts.
——. Society of Biblical Archæology.
——. Society of Public Analysts.
——. University College.
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Madison (Wis.).—University of Wisconsin.
Madrid.—Real Academia de Ciencias Exactas, Fisicas y Naturales.
Manchester Geological Society.
——. Literary and Philosophical Society.
Melbourne.—Royal Society of Victoria.
Mexico.—Sociedad Mexicana de Historia Natural.
Milan.—Giornale di Mineralogia.
——. Reale Instituto Lombardo di Scienze e Lettere.
——. Società Italiana di Scienze Naturali.
Minneapolis.—Minnesota Academy of Natural Sciences.
Montreal.—Natural History Society.
Moscow.—Société Impériale des Naturalistes.
Munich.—Konigliche Bayerische Akademie der Wissenschaften.
Newcastle-upon-Tyne. North of England Institute of Mining and Mechanical Engineers.
New Haven (Conn.).—American Journal of Science.
——. Connecticut Academy of Arts and Sciences.
New York.—Academy of Sciences.
——. American Institute of Mining Engineers.
Northampton.—Northamptonshire Natural History Society.
Oporto.—Sociedade Carlos Ribeiro.
Ottawa.—Royal Society of Canada.
Padua.—Reale Accademia di Scienze, Lettere ed Arti.
Palermo.—Annales de Géologie et de Paléontologie.
——. Reale Accademia di Scienze, Lettere ed Arti.
Paris.—Académie des Sciences.
——. Annuaire Géologique Universel.
——. Revue Scientifique.
——. Société Française de Minéralogie.
——. Société Géologique de France.
Penzance.—Royal Geological Society of Cornwall.
Philadelphia.—Academy of Natural Sciences.
——. American Philosophical Society.
——. Wagner Free Institute of Science.
Pisa.—Reale Università.
——. Società Toscana di Scienze Naturali.
Plymouth.—Devonshire Association for the Advancement of Science.
—— Institution, and Devon and Cornwall Natural History Society.
Port-of-Spain.—Victoria Institute of Trinidad.
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Rome.—Reale Accademia dei Lincei.
——. Società Geologica Italiana.
Rugby School Natural History Society.
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St. Petersburg.—Académie Impériale des Sciences.
——. Russische Kaiserliche Mineralogische Gesellschaft.
Santiago.—Deutscher Wissenschaftlicher Verein.
——. Sociedad Nacional de Mineria.
——. Société Scientifique du Chili.
Scranton (Pa.).—Colliery Engineer.
Stockholm.—Geologiska Forening.
——. Kongliga Svenska Vetenskaps Akademi.
Stuttgart.—Neues Jahrbuch für Mineralogie, Geologie und Paläontologie.
——. Verein fur Vaterlandische Naturkunde in Württemberg.
Sydney.—Linnean Society of New South Wales.
——. Royal Society of New South Wales.
Tokyo.—College of Science, Imperial University.
——. Imperial University.
——. Seismological Journal of Japan.
Toulouse.—Société d'Histoire Naturelle.
Truro.—Royal Institution of Cornwall.

Tufts College, Massachusetts.
Turin.—Reale Accademia delle Scienze.
Upsala Universitet.
—— Universitets Mineralogisk-Geologiska Institution.
Vienna.—Berg- und Hüttenmännisches Jahrbuch.
——. Kaiserliche Akademie der Wissenschaften.
——. Kaiserlich-königliche Zoologisch-botanische Gesellschaft.
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Wellington (N.Z.).—New Zealand Institute.
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York.—Natural History Journal.
——. Yorkshire Philosophical Society.

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Comparative Statement of the Number of the Society at the close of the years 1894 and 1895.

	Dec. 31st, 1894.		Dec. 31st, 1895.
Compounders	305	......	305
Contributing Fellows......	862	......	867
Non-contributing Fellows ..	75	......	69
	1242		1241
Foreign Members	40	......	39
Foreign Correspondents....	39	......	38
	1321		1318

Comparative Statement explanatory of the Alterations in the Number of Fellows, Foreign Members, and Foreign Correspondents at the close of the years 1894 *and* 1895.

Number of Compounders, Contributing and Non-contributing Fellows, December 31st, 1894 ..		1242
Add Fellows elected during former year and paid in 1895		12
Add Fellows elected and paid in 1895		32
		1286
Deduct Compounders deceased................	9	
Contributing Fellows deceased	10	
Non-contributing Fellows deceased	6	
Contributing Fellows resigned	10	
Contributing Fellows removed	10	
	—	45
		1241

Number of Foreign Members and Foreign Correspondents, December 31st, 1894		79	
Deduct Foreign Members deceased	4		
Foreign Correspondent deceased	1		
Foreign Correspondents elected Foreign Members	3		
	—	8	
		—	
		71	
Add Foreign Members elected		3	
Foreign Correspondents elected		3	
		—	77
			1318

DECEASED FELLOWS.

Compounders (9).

Ball, V., Esq.
Browne, Ven. Archdeacon.
Carter, R., Esq.
Cline, Dr. G. W.
Johnson, F., Esq.
Lawrence, P. H., Esq.
Mitchell, J., Esq.
Slatter, T. J., Esq.
Tylor, C., Esq.

Resident and other Contributing Fellows (10).

Bunbury, Sir E. H.
Carter, J., Esq.
Chance, E. J., Esq.
Copland-Crawford, Lt.-Gen. R.F.
Hosking, G. F., Esq.
Hulke, J. W., Esq.
Huxley, Rt. Hon. T. H.
Milnes, W. S., Esq.
Williams, J. E., Esq.
Wünsch, E. A., Esq.

Non-contributing Fellows (6).

Babington, Prof. C. C.
Duke, Rev. E.
Fitch, R., Esq.
Lester, Rev. Lester.
Mantell, W. B. D., Esq.
Tayler, J. W., Esq.

Foreign Members (4).

Dana, Prof. J. D.
Lovén, Prof. Sven.
Rütimeyer, Prof. L.
Saporta, Marquis G. de.

Foreign Correspondent (1).

Castillo, Don Antonio del.

Fellows Resigned (10).

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Plowright, H. J., Esq.
Routh, C. S., Esq.
Sherwood, W., Esq.
Whitmell, C. T., Esq.
Willett, H., Esq.
Winter, T., Esq.

Fellows Removed (10).

Ballard, Rev. F.
Browne, C., Esq.
Burns, D., Esq.
Gilpin, E., Esq.
Maude, Captain F. N.
Milles, R. S., Esq.
Muir, E., Esq.
Ratnavelacharia, M., Esq.
Rowlandson, T., Esq.
Wilson-Moore, C., Esq.

The following Personages were elected from the List of Foreign Correspondents to fill the vacancies in the List of Foreign Members during the year 1895:—

Monsieur F. Schmidt, of St. Petersburg.
Professor W. Dames, of Berlin.
Professor G. K. Gilbert, of Washington, U.S.A.

The following Personages were elected Foreign Correspondents during the year 1895:—

Dr. K. de Kroustchoff, of St. Petersburg.
Professor Paul Groth, of Munich.
Professor A. Penck, of Vienna.

After the Reports had been read, it was resolved:—

That they be received and entered on the Minutes of the Meeting, and that such parts of them as the Council shall think fit be printed and circulated among the Fellows.

It was afterwards resolved:—

That the thanks of the Society be given to Dr. Henry Woodward, retiring from the office of President.

That the thanks of the Society be given to W. H. Hudleston, Esq., retiring from the office of Vice-President.

That the thanks of the Society be given to Dr. G. J. Hinde, W. H. Hudleston, Esq., Prof. J. W. Judd, the Rev. H. H. Winwood, and H. B. Woodward, Esq., retiring from the Council.

After the Balloting-glasses had been duly closed, and the Lists examined by the Scrutineers, the following gentlemen were declared to have been duly elected as the Officers and Council for the ensuing year:—

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THE FOREIGN MEMBERS
OF THE GEOLOGICAL SOCIETY OF LONDON, IN 1895.

Date of Election.

1848. James Hall, Esq., *Albany, State of New York, U.S.A.*
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1856. Professor Robert Bunsen, For. Mem. R.S., *Heidelberg.*
1857. Professor H. B. Geinitz, *Dresden.*
1867. Professor A. Daubrée, For. Mem. R.S., *Paris.*
1871. Dr. Franz Ritter von Hauer, *Vienna.*
1874. Professor Albert Gaudry, *Paris.*
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1877. Dr. Eduard Suess, *Vienna.*
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1879. Dr. J. J. S. Steenstrup, For. Mem. R.S., *Copenhagen.*
1880. Professor Gustave Dewalque, *Liége.*
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1874. Dr. Henri Nyst.
1875. Mr. L. C. Miall.
1876. Professor Giuseppe Seguenza.
1877. Mr. R. Etheridge, Jun.
1878. Professor W. J. Sollas.
1879. Mr. Samuel Allport.
1880. Mr. Thomas Davies.
1881. Dr. R. H. Traquair.
1882. Dr. G. J. Hinde.
1883. Professor John Milne.
1884. Mr. E. Tulley Newton.
1885. Dr. Charles Callaway.
1886. Mr. J. S. Gardner.
1887. Mr. B. N. Peach.
1888. Mr. J. Horne.
1889. Mr. A. Smith Woodward.
1890. Mr. W. A. E. Ussher.
1891. Mr. R. Lydekker.
1892. Mr. O. A. Derby.
1893. Mr. J. G. Goodchild.
1894. Mr. Aubrey Strahan.
1895. Mr. W. W. Watts.
1896. Mr. Alfred Harker.

AWARDS OF THE MURCHISON MEDAL

AND OF THE

PROCEEDS OF THE 'MURCHISON GEOLOGICAL FUND,'

ESTABLISHED UNDER THE WILL OF THE LATE

SIR RODERICK IMPEY MURCHISON, BART., F.R.S., F.G.S.

'To be applied in every consecutive year in such manner as the Council of the Society may deem most useful in advancing Geological Science, whether by granting sums of money to travellers in pursuit of knowledge, to authors of memoirs, or to persons actually employed in any enquiries bearing upon the science of Geology, or in rewarding any such travellers, authors, or other persons, and the Medal to be given to some person to whom such Council shall grant any sum of money or recompense in respect of Geological Science.'

1873. Mr. William Davies. *Medal.*
1873. Professor Oswald Heer.
1874. Dr. J. J. Bigsby. *Medal.*
1874. Mr. Alfred Bell.
1874. Professor Ralph Tate.
1875. Mr. W. J. Henwood. *Medal.*
1875. Professor H. G. Seeley.
1876. Mr. A. R. C. Selwyn. *Medal.*
1876. Dr. James Croll.
1877. Rev. W. B. Clarke. *Medal.*
1877. Rev. J. F. Blake.
1878. Dr. H. B. Geinitz. *Medal.*
1878. Professor Charles Lapworth.
1879. Professor F. M'Coy. *Medal.*
1879. Mr. J. W. Kirkby.
1880. Mr. R. Etheridge. *Medal.*
1881. Sir Archibald Geikie. *Medal.*
1881. Mr. F. Rutley.
1882. Professor J. Gosselet. *Medal.*
1882. Professor T. Rupert Jones.
1883. Professor H. R. Göppert. *Medal.*
1883. Mr. John Young.
1884. Dr. H. Woodward. *Medal.*
1884. Mr. Martin Simpson.
1885. Dr. Ferdinand von Römer *Medal.*
1885. Mr. Horace B. Woodward.
1886. Mr. W. Whitaker. *Medal.*
1886. Mr. Clement Reid.
1887. Rev. P. B. Brodie. *Medal.*
1887. Mr. Robert Kidston.
Professor J. S. Newberry. *Medal.*
1888. Mr. Edward Wilson.
1889. Professor James Geikie. *Medal.*
1889. Professor G. A. J. Cole.
1890. Professor Edward Hull. *Medal.*
1890. Mr. E. Wethered.
1891. Professor W. C. Brögger. *Medal.*
1891. Rev. R. Baron.
1892. Professor A. H. Green. *Medal.*
1892. Mr. Beeby Thompson.
1893. Rev. O. Fisher. *Medal.*
1893. Mr. G. J. Williams.
1894. Mr. W. T. Aveline. *Medal.*
1894. Mr. George Barrow.
1895. Professor Gustav Lindström. *Medal.*
1895. Mr. A. C. Seward.
1896. Mr. T. Mellard Reade. *Medal.*
1896. Mr. Philip Lake.

AWARDS OF THE LYELL MEDAL

AND OF THE

PROCEEDS OF THE 'LYELL GEOLOGICAL FUND,'

ESTABLISHED UNDER THE WILL AND CODICIL OF THE LATE

SIR CHARLES LYELL, Bart., F.R.S., F.G.S.

The Medal 'to be given annually' (or from time to time) 'as a mark of honorary distinction and as an expression on the part of the governing body of the Society that the Medallist (who may be of any country or either sex) has deserved well of the Science,'—'not less than one third of the annual interest [of the fund] to accompany the Medal, the remaining interest to be given in one or more portions at the discretion of the Council for the encouragement of Geology or of any of the allied sciences by which they shall consider Geology to have been most materially advanced, either for travelling expenses or for a memoir or paper published, or in progress, and without reference to the sex or nationality of the author, or the language in which any such memoir or paper may be written.'

1876. Professor John Morris. *Medal.*
1877. Dr. James Hector. *Medal.*
1877. Mr. W. Pengelly.
1878. Mr. G. Busk. *Medal.*
1878. Professor W. Waagen.
1879. Professor Edmond Hébert. *Medal.*
1879. Professor H. A. Nicholson.
1879. Dr. Henry Woodward.
1880. Sir John Evans. *Medal.*
1880. Professor F. A. von Quenstedt.
1881. Sir J. W. Dawson. *Medal.*
1881. Dr. Anton Fritsch.
1881. Mr. G. R. Vine.
1882. Dr. J. Lycett. *Medal.*
1882. Rev. Norman Glass.
1882. Professor Charles Lapworth.
1883. Dr. W. B. Carpenter. *Medal.*
1883. Mr. P. H. Carpenter.
1883. M. E. Rigaux.
1884. Dr. Joseph Leidy. *Medal.*
1884. Professor Charles Lapworth.
1885. Professor H. G. Seeley. *Medal.*
1885. Mr. A. J. Jukes-Browne.
1886. Mr. W. Pengelly. *Medal.*
1886. Mr. D. Mackintosh.
1887. Mr. Samuel Allport. *Medal.*
1887. Rev. Osmond Fisher.
1888. Professor H. A. Nicholson. *Medal.*
Mr. A. H. Foord.
1888. Mr. Thomas Roberts.
1889. Professor W. Boyd Dawkins. *Medal.*
1889. M. Louis Dollo.
1890. Professor T. Rupert Jones. *Medal.*
1890. Mr. C. Davies Sherborn.
1891. Professor T. M^c^Kenny Hughes. *Medal.*
1891. Dr. C. J. Forsyth-Major.
1891. Mr. G. W. Lamplugh.
1892. Mr. G. H. Morton. *Medal.*
1892. Dr. J. W. Gregory.
1892. Mr. E. A. Walford.
1893. Mr. E. T. Newton. *Medal.*
1893. Miss C. A. Raisin.
1893. Mr. A. N. Leeds.
1894. Professor John Milne. *Medal.*
1894. Mr. William Hill.
1895. Rev. J. F. Blake. *Medal.*
1895. Mr. Percy F. Kendall.
1895. Mr. Benjamin Harrison.
1896. Mr. A. Smith Woodward. *Medal.*
1896. Dr. W. F. Hume.
1896. Mr. C. W. Andrews.

AWARDS OF THE BIGSBY MEDAL,

FOUNDED BY THE LATE

DR. J. J. BIGSBY, F.R.S., F.G.S.

To be awarded biennially 'as an acknowledgment of eminent services in any department of Geology, irrespective of the receiver's country; but he must not be older than 45 years at his last birthday, thus probably not too old for further work, and not too young to have done much.'

1877. Professor O. C. Marsh.
1879. Professor E. D. Cope.
1881. Dr. Charles Barrois.
1883. Dr. Henry Hicks.
1885. Professor Alphonse Renard.
1887. Professor Charles Lapworth.
1889. Mr. J. J. Harris Teall.
1891. Dr. George M. Dawson.
1893. Professor W. J. Sollas.
1895. Mr. Charles D. Walcott.

AWARDS OF THE PROCEEDS OF THE BARLOW-JAMESON FUND,

ESTABLISHED UNDER THE WILL OF THE LATE

DR. H. C. BARLOW, F.G.S.

'The perpetual interest to be applied every two or three years, as may be approved by the Council, to or for the advancement of Geological Science.'

1880. Purchase of microscope.
1881. Purchase of microscope-lamps.
1882. Baron C. von Ettingshausen.
1884. Dr. James Croll.
1884. Professor Leo Lesquereux.
1886. Dr. H. J. Johnston-Lavis.
1888. Museum.
1890. Mr. W. Jerome Harrison.
1892. Professor Charles Mayer-Eymar.
1893. Purchase of Scientific Instruments for Capt. F. E. Younghusband.
1894. Mr. Charles Davison.
1896. Mr. J. Wright.
1896. Mr. J. Storrie.

ESTIMATES *for*

INCOME EXPECTED.

	£	s.	d.	£	s.	d.
Compositions				136	0	0
Due for Arrears of Admission Fees	69	6	0			
Admission Fees, 1896	180	0	0			
				249	6	0
Arrears of Annual Contributions	110	0	0			
Annual Contributions, 1896, from Resident Fellows, and Non-Residents, 1859 to 1861	1630	0	0			
Annual Contributions in advance	35	0	0			
				1775	0	0
Dividends on £2000 India 3 per cents.	60	0	0			
Dividends on £2250 London and North-Western Railway 4 per cent. Preference Stock	90	0	0			
Dividends on £2800 London and South-Western Railway 4 per cent. Preference Stock	112	0	0			
Dividends on £300 London, Brighton, and South Coast Railway 5 per cent. Preference Stock	15	0	0			
Dividends on £1295 Midland Railway 4 per cent. Preference Stock	51	16	0			
				328	16	0
Sale of Quarterly Journal, including Longman's Account	150	0	0			
Sale of Geological Map, including Stanford's Account	10	0	0			
Sale of Transactions, Library Catalogue, Ormerod's Index, Hochstetter's 'New Zealand,' and List of Fellows	5	0	0			
				165	0	0
Balance against Society				608	6	0
				£3262	8	0

Note.—The following Funds are available for Extraordinary Expenditure.

	£	s.	d.
Balance at the Bankers', Dec. 31st, 1895	835	5	10
Balance in the Clerk's hands, Dec. 31st, 1895	16	9	7
	£851	15	5

the Year 1896.

EXPENDITURE ESTIMATED.

	£	s.	d.	£	s.	d.
House Expenditure:						
Taxes	0	15	0			
Fire Insurance	15	0	0			
Gas	25	0	0			
Fuel	30	0	0			
Furniture and Repairs	35	0	0			
House-repairs and Maintenance	30	0	0			
Annual Cleaning	15	0	0			
Washing and Sundries	25	0	0			
Tea at Meetings	15	0	0			
				190	15	0
Salaries and Wages, etc.:						
Assistant Secretary	300	0	0			
" Half Premium of Life Insurance	10	15	0			
Assistant Librarian	150	0	0			
Assistant Clerk	80	0	0			
House Porter and Upper-Housemaid	91	12	0			
Under-Housemaid	42	12	0			
Errand Boy	31	4	0			
Charwoman and Occasional Assistance	10	0	0			
Accountant's Fee	10	10	0			
				726	13	0
Library (Books and Binding)				250	0	0
Museum				5	0	0
Office Expenditure:						
Stationery	25	0	0			
Miscellaneous Printing	30	0	0			
Postages and other Expenses	80	0	0			
				135	0	0
Publications:						
Geological Map	10	0	0			
Quarterly Journal	850	0	0			
" " Commission, Postage, and Addressing	100	0	0			
Record of Geological Literature	75	0	0			
List of Fellows	35	0	0			
Abstracts, including Postage	110	0	0			
				1180	0	0
Index to Quarterly Journal, vols. 1–50 (sanctioned by Special General Meeting, June 21st, 1893)				375	0	0
Electric Lighting of Society's Apartments				300	0	0
Partial Redecoration of Society's Apartments				100	0	0
				£3262	8	0

Income and Expenditure during the

RECEIPTS.

	£	s.	d.	£	s.	d.
Balance in Bankers' hands, 1 January, 1895	345	1	8			
Balance in Clerk's hands, 1 January, 1895	13	7	5			
				358	9	1
Compositions				305	18	0
Arrears of Admission-fees	75	12	0			
Admission-fees	182	14	0			
				258	6	0
Arrears of Annual Contributions				157	12	7
Annual Contributions of 1895:						
Resident Fellows	1624	17	6			
Non-Resident Fellows	11	0	6			
				1635	18	0
Annual Contributions in advance				39	18	0
Taylor & Francis: Advertisements in Journal, Vol. 50					15	0
Publications:						
Sale of Journal, Vols. 1–50	85	0	3			
„ Vol. 51 *	72	12	8			
Sale of Library Catalogue		5	0			
Sale of Geological Map	9	3	0			
Sale of Ormerod's Index		14	2			
Sale of Hochstetter's 'New Zealand'		6	0			
Sale of List of Fellows		8	3			
				168	9	4
Dividends on L. & N. W. Railway Stock	87	0	0			
„ L. & S. W. Railway Stock	108	5	4			
„ L. B. & S. C. Railway Stock	14	10	0			
„ Midland Railway Stock	25	0	9			
„ $2\frac{3}{4}$ p. c. Consolidated Stock	50	2	0			
„ India 3 p. c. Stock	29	0	0			
				313	18	1
Sale of £3769 2*s.* 6*d.* $2\frac{3}{4}$ p. c. Consolidated Stock at $104\frac{3}{8}$				3934	0	6
Income Tax:						
Repayment of Tax under Schedule C for the year 1894–95				10	9	3
				£7183	13	10

*Due from Messrs. Longmans, in addition to the above, on Journal, Vol. 51, £62 8*s.* 1*d.*

We have compared this Statement with the Books and Accounts presented to us, and find them to agree.

(Signed) B. H. BROUGH, R. S. HERRIES, } *Auditors.*

January 27th, 1896.

Year ended December 31st, **1895.**

PAYMENTS.

				£	s.	d.	£	s.	d.
House Expenditure:									
Taxes				3	15	0			
Fire Insurance				15	0	0			
Gas				24	9	7			
Fuel				26	9	11			
Furniture and Repairs				55	4	11			
House Repairs				29	7	4			
Annual Cleaning				10	15	0			
Washing and Sundries				22	13	2			
Tea at Meetings				13	12	1			
							201	7	0
Salaries and Wages:									
Assistant Secretary				250	0	0			
„ Half Life Insurance premium				10	15	0			
Assistants in Library, Office, and Museum				251	5	6			
House Porter and Upper-Housemaid (including Uniform and Allowance for Washing)				91	13	3			
Housemaid (including Allowance for Washing)				42	13	3			
Errand Boy				29	8	0			
Charwoman and Occasional Assistance				4	19	0			
Accountant's Fee				10	10	0			
							691	4	0
Office Expenditure:									
Stationery				25	4	2			
Miscellaneous Printing				43	11	1			
Postages and Sundry Expenses				89	5	10			
Gratuities to Assistant-Secretary and Assistant-Librarian				40	0	0			
							198	1	1
Library							171	0	6
Museum							50	0	0
Publications:									
Geological Map				4	15	7			
Journal, Vols. 1–50				7	11	2			
„ Vol. 51	738	14	1						
„ „ Commission, Postage, and Addressing	85	9	0						
				824	3	1			
List of Fellows				35	18	4			
Abstracts, including Postage				107	4	5			
Geological Literature				32	0	9			
Index to Quarterly Journal				75	0	0			
							1086	13	4
Investment in £2000 India 3 p. c. Stock at 104				2082	13	0			
Ditto in £1295 Midland Railway 4 p. c. Perp. Pref. Stock at 141½				1850	19	6			
							3933	12	6
Balance in Bankers' hands, 31 Dec. 1895				835	5	10			
Balance in Clerk's hands, 31 Dec. 1895				16	9	7			
							851	15	5
							£7183	**13**	**10**

W. T. BLANFORD, ***Treasurer.***

'WOLLASTON DONATION FUND.' TRUST ACCOUNT.

RECEIPTS.	£	s.	d.	PAYMENTS.	£	s.	d.
Balance at Bankers', January 1st, 1895	22	10	5	Cost of striking Gold Medal awarded to Sir A. Geikie	10	10	0
Dividends on the Fund invested in $2\frac{3}{4}$ per cent. Consolidated Stock	14	8	2	Award to Mr. W. W. Watts	19	4	6
Ditto Hampshire County 3 per cent. Stock	15	11	2	Purchase of £1073 Hampshire County 3 per cent. Stock at $105\frac{5}{8}$	1134	15	11
Repayment of one year's Income Tax under Schedule C		19	9	Balance at Bankers', December 31st, 1895	23	15	0
Sale of £1084 1*s.* 1*d.* Consolidated $2\frac{3}{4}$ per cent. Stock at $104\frac{5}{8}$	1134	3	10				
Transfer from Geological Society		12	1				
	£1188	5	5		£1188	5	5

'MURCHISON GEOLOGICAL FUND.' TRUST ACCOUNT.

RECEIPTS.	£	s.	d.	PAYMENTS.	£	s.	d.
Balance at Bankers', January 1st, 1895	20	10	2	Award to Professor G. Lindström, with Medal	10	10	0
Dividends on the Fund invested in London and North-Western Railway 3 per cent. Debenture Stock	38	13	8	" Mr. A. C. Seward	28	10	0
Repayment of one year's Income Tax under Schedule C	1	5	10	Cost of Medal		17	0
				Balance at Bankers', December 31st, 1895	20	12	8
	£60	9	8		£60	9	8

'LYELL GEOLOGICAL FUND.' TRUST ACCOUNT.

RECEIPTS.	£	s.	d.	PAYMENTS.	£	s.	d.
Balance at Bankers', January 1st, 1895	53	2	8	Award to Rev. J. F. Blake, with Medal	35	0	0
Dividends on the Fund invested in Metropolitan $3\frac{1}{2}$ per cent. Stock	68	0	4	" Mr. B. Harrison	17	0	10
Repayment of one year's Income Tax under Schedule C	2	6	8	" Mr. P. F. Kendall	17	0	11
				Cost of Medal	1	1	0
				Balance at Bankers', December 31st, 1895	53	6	11
	£123	9	8		£123	9	8

'Barlow-Jameson Fund.' Trust Account.

Receipts.	£	s.	d.
Balance at Bankers', st January, 1895	38	17	3
Dividends on the Fund invested in 2$\frac{3}{4}$ per cent. Consolidated Stock	6	13	0
Dividends on the Fund invested in Great Northern Railway 3 per cent. Debenture Stock	6	15	9
Repayment of one year's Income Tax under Schedule C		9	0
Sale of £500 2$\frac{3}{4}$ per cent. Consolidated Stock at 104$\frac{5}{8}$	523	2	6
Transfer from Geological Society		3	3
	£576	0	9

Payments.	£	s.	d.
Purchase of £468 Great Northern Railway 3 per cent. Debenture Stock at 110$\frac{5}{8}$	523	5	9
Balance at Bankers', 31st December, 1895	52	15	0
	£576	0	9

'Bigsby Fund.' Trust Account.

Receipts.	£	s.	d.
Balance at Bankers', 1st January, 1895	10	1	7
Dividends on the Fund invested in 2$\frac{3}{4}$ per cent. Consolidated Stock	2	15	8
Dividends on the Fund invested in Cardiff Corporation 3 per cent. Stock	3	0	11
Repayment of one year's Income Tax under Schedule C		3	10
Sale of £209 8*s*. 6*d*. 2$\frac{3}{4}$ Consolidated Stock at 104$\frac{3}{5}$	219	2	3
Transfer from Geological Society		14	0
	£235	18	3

Payments.	£	s.	d.
Cost of striking Gold Medal awarded to Mr. C. D. Walcott	11	9	5
Purchase of £210 Cardiff Corporation 3 per cent. Stock at 104$\frac{1}{2}$	219	16	3
Balance at Bankers', 31st December, 1895	4	12	7
	£235	18	3

W. T. BLANFORD, *Treasurer.*

Valuation of the Society's Property; December 31st, 1895.

Property.	£	s.	d.		£	s.	d.
Due from Longmans & Co., on account of Journal, vol. LI. etc.	62	8	1	Balance in favour of the Society	12,035	15	3
Balance in Bankers' hands, 31 Dec. 1895	835	5	10				
Balance in Clerk's hands, 31 Dec. 1895	16	9	7				
Funded Property:—							
£2000 India 3 per Cents	2082	13	0				
£2250 London & North-Western Railway 4 per cent. Consolidated Preference Stock	2898	10	6				
£2800 London & South-Western Railway 4 per cent. Preference Stock	3607	7	6				
£500 London, Brighton, & South Coast Railway 5 per cent. Consolidated Preference Stock	502	15	3				
£1295 Midland Railway 4 per cent. Preference Stock	1850	19	6				
Arrears of Admission-fees	69	6	0				
Arrears of Annual Contributions	110	0	0				
[*N.B.—The above does not include the value of the Collections, Library, Furniture, and Stock of unsold Publications.*]	£12,035	15	3		£12,035	15	3

W. T. BLANFORD, *Treasurer.*

January 27th, 1896.

Note.—The investments in Stocks are valued at their cost price. Their aggregate selling-price on December 31st, 1895, at the quotations of the day, exceeds the above amounts by more than £1500.

Award of the Wollaston Medal.

In handing the Wollaston Medal to Sir John Evans, K.C.B., D.C.L., F.R.S., F.L.S., Foreign Secretary (for transmission to Eduard Suess, Ph.D., For.Memb.R.S., For.Memb.G.S., Professor of Geology in the University of Vienna), the President addressed him as follows:—

Sir John Evans,—

May I request you in your official capacity, as Foreign Secretary, to receive and transmit to our esteemed Foreign Member, Prof. Eduard Suess, of the University of Vienna, this Medal, founded by that eminent man, Dr. Wollaston, in 1828, 'to promote researches concerning the mineral structure of the earth, and to enable the Council of the Geological Society to reward those individuals of any country, by whom such researches may hereafter be made.' Of the 27 occasions on which this Medal has been transmitted to foreigners it has twice before been awarded to Austrian Geologists, namely, in 1857, to the illustrious Barrande, and in 1882, to Franz Ritter von Hauer, Intendant of the Imperial Museum of Natural History in Vienna and Director of the Geological Survey of Austria.

In speaking of a man so well known as Prof. Suess, words of commendation on my part are hardly needful. For 39 years he has occupied the Chair of Geology in the University of Vienna, and has exercised an influence on the work of the distinguished school of geologists in that city—including such men as Neumayr, Mojsisovics, Fuchs, Waagen, Penck, and many others—which proves him to be a great master of our science. Since 1851 a steady stream of Memoirs, issued by him, has proved him to be a great worker in Geology; while the intellectual stimulus of his writings on foreign geologists shows him to be a great thinker. He is worthy of this Award, therefore, not only for the work which he has accomplished himself, but by what he has roused others to do, not only by the originality of his own thought, but by the extent to which he has influenced the minds of others.

Suess is not a specialist. He began work on Graptolites; he next laid the foundations of the modern classification of the Brachiopoda and Ammonites. Alpine problems roused his interest in Dynamical and Structural Geology, and led to studies of the Austrian and Italian earthquakes, and to his suggestions of the connexion between these and the great circle of European Tertiary

Volcanoes and the elevation of the Alps. Work on the complex Tertiaries of the Vienna Basin and a study of the Mediterranean littoral geology led to his researches in Faunistic Palæontology, and so prepared the way for his pupil Neumayr.

Suess's varied knowledge, penetrative insight, and suggestive originality are perhaps best exhibited in his 'Antlitz der Erde,' wherein he tried to show the main factors and methods that have ruled in geographical evolution.

The intimate union thus established between the problems of Geology and Geography cannot but be regarded as of the highest importance to the advancement of both sciences, and the world has been made wiser by the rich stores of knowledge which Prof. Suess has garnered for geologists and geographers in all countries.

Prof. Suess has been connected with this Society since 1863, in which year I made his personal acquaintance when he visited London. He has now been a Foreign Member since 1876, and is one of the three oldest foreign geologists on the Society's List. His attachment to this country will be better understood when it is known that Prof. Suess was born in London on the 20th of August, 1831, his father being at that time a merchant in the City.

I am sure it will add to Prof. Suess's pleasure to be told that this Medal was awarded him by the unanimous vote of the Council, and that we send, with it, our warmest remembrances and good wishes for his continued health and prosperity.

Sir John Evans, in reply, said :—

Mr. President,—

The recipient of this Award, whose professorial duties as well as his advancing age prevent him from attending this Meeting, has requested me to read the following communication from him :—

'By adding my name to the list of those Masters of Geological Science who have been honoured before me by the award of the Wollaston Medal, your illustrious Society renders me truly proud, and I can hardly find words adequate to express my feelings of gratitude.

'In addition to field-work, I have for many years laboured to obtain some approximately comprehensive view of the surface-structure

of the whole of our planet, and during this endeavour not a day has passed without bringing again and again before my eyes the vastness of the British Empire, the world-wide activity of British geologists and travellers, and the enormous amount of geological work and learning recorded in the English language.

'I often and gladly remember the kindness and the instruction which during the course of my life I have received from my English masters, and above all from my repeated intercourse with Sir Charles Lyell, but I dared not think that my own modest essays would ever be deemed worthy of this distinction—the highest that English geologists can bestow.

'This, however, now comes to me at an age when the natural diminution of physical strength confines me to valley and home; hammer and belt rest on their peg, and dreams and remembrances alone still carry me along those Alpine wanderings which form the highest charm of our incomparable science, and in the lonely grandeur of which Man feels himself more than ever a child of surrounding Nature.

'In these hours of enforced inactivity, the Award of your Society leads me to hope that my past exertions have not been quite in vain; and with deepest thanks I receive this Medal as a token of indulgence, of encouragement, and also of consolation.'

Award of the Wollaston Donation Fund.

The President then presented to Alfred Harker, Esq., M.A., F.G.S., of the Geological Survey of Scotland, and of St. John's College, Cambridge, the Balance of the Proceeds of the Wollaston Donation Fund, addressing him as follows:—

Mr. Harker,—

The Council request your acceptance of the Wollaston Fund in recognition of your admirable work in Petrology and your studies in the Metamorphic and Igneous Rocks and in Dynamometamorphism, to which you have given such careful attention since you joined our ranks as a Fellow in 1884.

I have only to allude to your papers before this Society on the Gabbro of Carrock Fell and its Granophyres; your petrological notes on rocks from the Cross-Fell Inlier; your paper on the

eruptive rocks of Sarn, Caernarvonshire; your joint papers with Mr. Marr on the Shap Granite and the associated Metamorphic Rocks,—to show the nature of the work in which you have been engaged.

Your Sedgwick Essay, on the Volcanic Rocks of Caernarvonshire, is a model of what such work should be. It has already received a well-merited encomium from your present chief, the Director-General of the Geological Survey.

In the past twelve years you have also been a frequent contributor to the pages of the 'Geological Magazine,' in which some twenty articles of yours are to be found.

Lastly, your excellent 'Petrology for Students,' issued from the Cambridge University Press last year, greatly adds to your credit in this field of research.

This slight recognition from the Council may serve to assure you how highly your past work has been appreciated, and how much more good work we trust that you will live to achieve.

Mr. Harker, in reply, said:—

Mr. President,—

I heartily thank the Council for the honour which they have conferred upon me, and yourself for the graceful words with which you have accompanied this Award.

In the work to which you have made kind reference, I have confined myself to only one among the several lines of research recognized by this Society. I have, however, always regarded Petrology, not as a study apart, but as a branch of Geological Science; and whatever value may belong to my results, I owe in large measure to the fortunate circumstances which have enabled me constantly to combine work in the field with work in the laboratory.

Generous appreciation at the hands of those best qualified to judge is an incentive second only to the pleasure of the work itself. To the encouragement which I have at all times derived from the comradeship of fellow-workers, both at Cambridge and elsewhere, is now added that which must always attach to such an honour as the present one; and for the encouragement, no less than for the recognition, I tender my best thanks.

AWARD OF THE MURCHISON MEDAL.

In presenting the Murchison Medal to T. MELLARD READE, Esq., C.E., F.G.S., the PRESIDENT said:—

Mr. MELLARD READE,—

The Council of the Geological Society have awarded to you the Murchison Medal, in recognition of your work on 'The Origin of Mountain Ranges,' containing the records of much original and experimental research. Since you joined this Society in 1872 you have contributed to the various scientific Journals, and to this and other kindred institutions, more than a hundred papers on geological subjects, treating of 'the Geology and Physics of the post-Glacial Period in Lancashire and Cheshire,' 'the Buried Valley of the Mersey,' 'the Drift-beds of the North-West of England,' 'the Chalk-masses in the Contorted Drift of Cromer,' 'Tidal Action as a Geological Cause,' 'the Moon and the Earth,' and many other kindred subjects bearing upon Dynamical Geology, to which you have devoted much careful thought and originality of observation extending over more than a quarter of a century, and have never permitted an opportunity to slip of adding to our store of geological knowledge.

This Medal will serve to assure you that, although not often present at our Meetings, and living at a distance from town, you are neither overlooked nor forgotten by your fellow-geologists here, nor have your labours been unappreciated.

Mr. MELLARD READE replied as follows:—

Mr. PRESIDENT,—

It is with mingled feelings difficult, nay impossible, to express here, that I receive the Medal founded by the illustrious author of 'Siluria,' which the Council of this Society, in the exercise of their functions, have thought fit to award to me. If one circumstance more than another could add to the pleasure which the Award affords me, it is, Dr. Woodward, that I receive it through you as President of this Society. I cannot forget that my first little geological venture was launched in the columns of the 'Geological Magazine,' and that ever since you have proved to be a true and consistent friend.

As regards the work and researches of which you have so favourably spoken, it is for others to assess their value, and for me to

rejoice that they have been considered worthy of so handsome a recognition. Like the founder of this Medal, I began the study of Geology in middle life, and doubtless the direction and the character of my researches have been profoundly influenced by previous professional training as well as by natural bias. The study of Geology has been to me a labour of love as well as an interesting and healthful recreation. It has also been an education. Doubtless some of the work to which I have directed my attention has been of an arduous nature; but, as Shakespeare says,

'The labour we delight in physics pain.'

It now only remains for me to thank the Council and yourself for this much appreciated recognition of my small services to Geological Science, and to assure you that the addition of my name to the distinguished list of Murchison Medallists is calculated to inspire and support me in any further work which in God's providence I may be permitted to carry out.

Award of the Murchison Geological Fund.

The President then presented the Balance of the Proceeds of the Murchison Geological Fund to Philip Lake, Esq., M.A., F.G.S., addressing him in the following words:—

Mr. Lake,—

The Council of the Geological Society have awarded to you the Balance of the Proceeds of the Murchison Geological Fund, in recognition of your work in India, too soon interrupted by ill-health. Before you left, however, you had made a solid contribution to the history of the origin of the remarkable Laterites of that region (Mem. Geol. Surv. India, vol. xxiv. Art. 3, 1890), as well as to some other Indian geological problems. You have now commenced in Wales: first, in conjunction with Mr. T. T. Groom, at Corwen (Quart. Journ. Geol. Soc. 1893, vol. xlix. p. 426), and at a later date alone, near Llangollen (*ibid.* 1895, vol. li. p. 9), you have given the Society careful and accurate contributions on the Geology of these difficult regions.

Nor have you neglected Palæontological studies, as your recent paper on *Acidaspis* bears testimony.

It is hoped that this Award may prove not only useful, but that it may serve as an incentive to continued and important geological work in the near future.

Mr. Lake, in reply, said:—

Mr. President,—

I am deeply sensible of the honour which the Council have done me in making this Award: for to a labourer in the cause of science there is no truer pleasure than the appreciation of his labours by his fellow-workers. It is an additional gratification that it should fall to my lot to receive the Award at your hands, since of late I have attempted to follow in your footsteps in the field which you have made so peculiarly your own.

I feel, however, that the Award is a recognition far beyond what my work has hitherto deserved; and I look upon it rather as an encouragement to persevere in the researches which I have begun.

Award of the Lyell Medal.

In presenting the Lyell Medal to Arthur Smith Woodward, Esq., F.L.S., F.G.S., the President said:—

Mr. Arthur Smith Woodward,—

The Council of the Geological Society have awarded you the Lyell Medal, because it appeared to them that the Palæontological work to which you have so earnestly devoted your life since you commenced your career in the British Museum in 1882 would have met with the cordial approval of the distinguished geologist and writer who founded this Award.

Trained at the Owens College, Manchester, you had, besides this, an innate love of scientific work, and only needed the opportunity to develop into an accomplished palæontologist of the Vertebrata.

In dealing with the whole field of Fossil Vertebrata, you wavered at first between the varied groups to which your studies invited you; but, after a few papers on Mammalia and Reptilia, you turned with a steady resolve to the study of Fossil Fishes, from which you have scarcely ever departed. More than one hundred papers on Fossil Fishes, besides a descriptive and illustrated Catalogue of Fossil Fishes in the British Museum, of which three volumes have already appeared (1889–95), and two Memoirs on the Fossil Fishes of New South Wales, attest the settled life-line of research to which you now stand committed.

But we have to thank you also for a joint work with Mr. C. Davies Sherborn, F.G.S., of the very greatest usefulness to palæontologists, 'A Catalogue of British Fossil Vertebrata,' 1890—a most trustworthy and excellent compilation, critically and carefully prepared.

That in the space of fourteen years you should have accomplished so much good work, is due to the fact that you have never wavered from the object which you had set before your mind to accomplish, and even in your numerous journeys in Europe and to North America you have ever kept your Ichthyological researches steadily in view.

I trust that this Medal, and the good wishes which accompany it from your friends here, will encourage you to the completion of your labours on the Fossil Fishes, and that the remaining group of the Teleosteans may enjoy the same careful and critical attention and study at your hands as you have bestowed upon the other and earlier groups.

Mr. Smith Woodward, in reply, said:—

Mr. President,—

I desire to express my thanks to the Council of the Geological Society for the great honour that they have done me in making this Award, and to yourself, Sir, for the very kind and complimentary terms in which you have presented the Medal. During the last thirteen years I have merely tried to make the best use of the opportunities for research afforded by my official connexion with the British Museum; and the gratification experienced in the pursuit of duty of this kind is in itself so ample a reward for the labour involved, that a naturalist thus circumstanced scarcely looks for anything beyond it. When, however, the honourable marks of approbation officially bestowed are unexpectedly coupled with so highly esteemed a distinction as the award of the Lyell Medal by the Geological Society of London, I feel doubly encouraged to persevere and endeavour to merit the compliments that have been expressed.

I was first led to take a special interest in extinct Fishes by attending Dr. Traquair's course of Swiney Lectures on the subject in 1883. I was thus enabled to apply to this field of research the methods that I had previously learned from Prof. Boyd Dawkins when a student in the Owens College. Since that time the kindly encouragement of so many friends—yourself and the late Mr. William Davies among the foremost—has made progress easy; and the very

fortunate circumstance that most of the larger private collections of Fossil Fishes in this country have now been acquired by the British Museum, has afforded me favourable opportunities for study such as have never been enjoyed by any one previously. The biological problems suggested by these fossils seem to me to outweigh in interest the geological questions connected with them to so great a degree, that I have rarely been able to look upon them from any but a morphologist's point of view; and all the more on this account do I appreciate the high honour that is conferred upon me by the Geological Society to-day.

Award of the Lyell Geological Fund.

The President then presented one-half of the Balance of the Proceeds of the Lyell Geological Fund to Dr. William Fraser Hume, Assoc.R.S.M. & R.Coll.Sci., F.G.S., and addressed him as follows:—

Dr. Hume,—

Although for several years you have been actively engaged as a Demonstrator in Geology in the Royal College of Science, you have not allowed any opportunities for doing original work in the field to escape you; and your essay on the Chemical and Micro-mineralogical Structure of the several zones of the Upper Cretaceous rocks of the South of England illustrates admirably how such detailed work should best be carried out.

Your papers on the 'Black-Earth,' 'the Loess,' and on the Chalk of Russia, 'on the Genesis of the Chalk,' and on 'Oceanic Deposits,' indicate the bent of your researches towards the microscopic investigation of rocks—a line of study which Dr. H. C. Sorby, F.R.S., a past President of this Society, so profitably engaged in.

The Council hope, by the presentation of this Award, not only to mark their appreciation of your past researches, but to encourage you to extend them to other formations with the same useful results.

Dr. Hume replied as follows:—

Mr. President,—

At times a feeling of despondency has crossed my mind, when I

have considered the vastness of our subject, and the smallness of the contributions which I have endeavoured to add to our knowledge of the past; it is therefore a great encouragement to receive this mark of approval from those whose opinion we most value and esteem. It would, indeed, have been strange if, with the resources of the Royal College of Science at my disposal, I had not availed myself to the utmost of such exceptional opportunities.

Two facts afford me special gratification on the present occasion: the first, that this Award should be intimately connected with the great geologist whose historical and geographical methods I have been most anxious to follow to the best of my ability; the second, to receive it from you, seeing that you were the editor who piloted with friendly hand my first publication, at a time when it was especially in your power to damp or re-inspire the ardour of a young enthusiast. Therefore, to you, Sir, to the Council, and to the kind friends who have aided me by active counsel or friendly criticism, I hereby tender my most warm and hearty thanks.

The PRESIDENT then handed the other moiety of the Balance of the Proceeds of the Lyell Geological Fund to CHARLES W. ANDREWS, Esq., B.A., B.Sc., F.G.S., of the British Museum (Natural History), and addressed him as follows:—

Mr. ANDREWS,—

Although your scientific career has been but a short one, you have lost no time in engaging in active and earnest studies in the Comparative Osteology of the Fossil and Living Vertebrata, and have already done some excellent work on the remains of the extinct gigantic Birds from Madagascar and from other parts of the world. Your papers on *Keraterpeton* from the Coal Measures, and on the Oxfordian genera of Plesiosauria, prove that you have already acquired an accurate knowledge of many points of detail in the structure of these extinct Reptiles which can only be appreciated by an equally careful study of existing forms.

In making this Award, the Council desire not only to assist and encourage you in the work which you have taken in hand with so much enthusiasm, but they have a confident expectation that you will ere long contribute papers to their Proceedings, which shall do honour to their prescience and bring κῦδος to yourself.

Mr. ANDREWS, in reply, said :—

Mr. PRESIDENT,—

I wish to express my sincere thanks to the Council for the great honour that they have done me, and to you, Sir, for the altogether too kind remarks that you have made. It was always my earnest desire to study the structure of animals, but in my wildest dreams I never hoped to have such opportunities as I now enjoy at the Natural History Museum, and I feel continually a sense of responsibility and fear lest I should prove unequal to the task which lies before me. Having now received this Award, I am still further bound in honour to do my utmost to justify it, and to fulfil as far as possible the expectations that you have expressed.

AWARD OF THE BARLOW-JAMESON FUND.

In handing a moiety of the Barlow-Jameson Fund to Dr. G. J. HINDE, F.G.S. (for transmission to JOSEPH WRIGHT, Esq., F.G.S., of Belfast), the President addressed him as follows :—

Dr. HINDE,—

The Council have awarded the sum of Twenty Pounds from the Barlow-Jameson Fund to Mr. Joseph Wright, in recognition of the valuable services that he has rendered to the Palæontology, not only of the Carboniferous rocks in the South, but of the Cretaceous and Post-Tertiary deposits in the North of Ireland, and the Glacial deposits there, and in Scotland.

Mr. Wright is the author of numerous papers in the Transactions of the Belfast Naturalists' Field-Club, on the Irish Liassic and Cretaceous Foraminifera and other Microzoa; he has also prepared and published many lists of Foraminifera from the Scottish and Irish Boulder-Clay and other post-Tertiary deposits.

He has done much good work, extending over many years, when resident in the South of Ireland, in connexion with the fossils of the Carboniferous Limestone, and both as regards these, and the newer deposits of the North, his specimens have been always available to any one engaged in writing on the fossils. To Davidson, Rupert Jones, Holl, Brady, myself, and others Joseph Wright's cabinet was ever accessible and his specimens were freely lent for study.

I trust that this Award will serve to express to Mr. Wright our appreciation of his services, and will act as an incentive to him to continue his useful geological work.

Dr. HINDE replied as follows :—

Mr. PRESIDENT,—

It gives me great satisfaction to receive this Award on behalf of my friend Mr. Joseph Wright. He is unfortunately unable to be present, and has sent the following letter for communication to you :—

'I desire to express my sincere thanks for the honour conferred upon me by the Council of our Society in recognition of my past work, and for their assistance in the further prosecution of my researches. Working so remote from the headquarters of the Society causes this Award to be the more appreciated.

'I regret that I am prevented from being present to receive it in person, but I hope that the Council will accept this expression of my feelings regarding their approval of my work in a somewhat neglected field.

'For some years past nearly all my spare time has been spent in microscopically examining the Glacial Clays for Foraminifera. My anticipation as to the occurrence of these organisms in Clays laid down under glacial conditions has been fully confirmed both as regards our local deposits and other British Clays, and I cannot avoid thinking that this fact must more or less influence our views as to the origin of these drifts.'

In handing to A. STRAHAN, Esq., M.A., F.G.S. (for transmission to Mr. JOHN STORRIE, of Cardiff), the second moiety of the Award made from the Barlow-Jameson Fund, the PRESIDENT addressed him as follows :—

Mr. STRAHAN,—

The Council have accorded to Mr. Storrie the sum of Twenty Pounds from the Barlow-Jameson Fund, in recognition of his services for the advancement of Geological Science while in charge of the Cardiff Museum, and, subsequently, as a volunteer worker on the Geology of South Wales. Mr. Storrie, I am informed, was the first to detect and describe an actual exposure of the base of the Old Red Sandstone near Rumney, and his researches have done

much to elucidate the obscure plant-remains from the Silurian rocks of that locality.

In the Rhætic and Triassic strata he found and fixed the exact horizon of certain fossils new to the district, while in the latter he made an interesting discovery of grains of gold. His intimate and accurate knowledge of the Cardiff area proved of great service to Geologists at the time when the British Association held its meeting in that town. Indeed few Geologists have worked in the neighbourhood of Cardiff without being indebted to him for assistance.

I have much pleasure in handing you this Award for transmission to Mr. Storrie.

Mr. Strahan, in reply, said:—

Mr. President,—

It will be a great pleasure to me to forward this Award to Mr. Storrie. The pages of our Journal testify to the value of the aid that he has rendered to many Fellows of the Society. I have myself been indebted to him for most valuable assistance in the geological mapping of the neighbourhood of Cardiff. Mr. Storrie writes to me:—

'I regret that it will not be in my power to attend personally to thank the President and Council for the great honour that they have done me.

'I am afraid that up to now I have not done enough to warrant my selection, but if ever I am able in future to do anything in the way of original work I shall be very anxious to justify this choice and give my whole mind to the accomplishment of the best work possible.

'You will, I hope, convey in better words than I can the extreme gratitude which I feel for the Award.'

THE ANNIVERSARY ADDRESS OF THE PRESIDENT,

HENRY WOODWARD, LL.D., F.R.S.

GENTLEMEN,—

The past year has left behind it a long and mournful record in our 'Street of Tombs,' and, as my own allotted time is so brief to-day, I would suggest that we should each entwine a garland of laurels and immortelles in memory of those whose names we honour, and so, hammer in hand, go forward.

Of aged Fellows, one, Robert Fitch, of Norwich, had reached his 93rd year. He was a contemporary of my father, Samuel Woodward, the Norfolk geologist, but twelve years his junior. Six Fellows and two Foreign Members—namely, Prof. C. C. Babington, the Ven. Archdeacon Browne, Sir E. H. Bunbury, James Carter of Cambridge, Mr. E. J. Chance, Gen. Copland-Crawford, Prof. J. D. Dana, and Prof. Sven Lovén—were between 80 and 90 years of age. Six Fellows and two Foreign Members—the Marquis de Saporta, Rt. Hon. T. H. Huxley, Prof. L. Rütimeyer, the Hon. Walter Mantell, Mr. P. H. Lawrence, Mr. E. A. Wünsch, the Rev. E. Duke, and Mr. Richard Carter—were between 70 and 80 years of age. Eight Fellows—namely, Mr. J. W. Hulke, For. Sec., Mr. T. J. Slatter, Dr. J. E. Taylor, Mr. Charles Tyler, Rev. Lester Lester, Mr. J. Walter Tayler, Mr. W. S. Milnes, and Dr. G. W. Cline —were between 60 and 70. The remaining five were between 35 and 60:—Prof. Valentine Ball, C.B., Mr. J. Mitchell, Mr. G. F. Hosking, Mr. Hugh Miller, and Mr. J. E. Williams.

We have lost two Past Presidents: the Rt. Hon. T. H. Huxley, P.C., and Mr. J. W. Hulke, For. Sec.; four Foreign Members: namely, the Marquis de Saporta (France), Prof. J. D. Dana (United States of America), Prof. S. Lovén (Sweden), Prof. L. Rütimeyer, M.D. (Switzerland); and one Foreign Correspondent, Sr. Don Antonio del Castillo (Mexico).

Three of these were also Wollaston Medallists. Another Wollaston Medallist died last year who was not a Fellow of this Society,—Prof. W. C. Williamson, F.R.S. (*æt.* 78). Williamson was distinguished as a palæobotanist, and was for many years Professor of Botany in Owens College, Manchester. His collection, illustrative of the structure of Fossil Plants of the Coal-Measures, has just been acquired by the Trustees of the British Museum.

The Marquis of Saporta, who was a Corresponding Member of the Institute of France, and a Foreign Member of the Geological Society of London since 1889, was born at Saint-Zacharie (Var) in 1823. He spent some time in a Jesuit college at Fribourg, and in 1861, in conjunction with M. Matheron, published his first paper on a palæobotanical subject, 'Examen analytique des Flores tertiaires de Provence.' From that date up to the time of his death, which occurred on January 26th, 1895, Saporta devoted himself, as a keen student, to the problems of his chosen science.

His earlier works dealt especially with the Tertiary vegetation of the South-east of France: the floras of Aix, Manosque, Sézanne, and other localities, have formed the subjects of elaborate monographs, in which he has not merely recorded lists of fossil species, but has dealt with the facts from a broad and philosophic standpoint. Between the years 1872–91 there appeared the splendid series of volumes on 'the Jurassic Flora of France': this comprehensive work, with its numerous illustrations and exhaustive text, forms an indispensable handbook to students of Mesozoic Botany. Saporta's most recent work, on 'Upper Jurassic and Lower Cretaceous Plants,' appeared a few months before his death, 'Flore fossile du Portugal (Direction des Travaux géologiques du Portugal), 1895.' It contains a detailed geological and botanical analysis of an exceedingly interesting flora, and supplies fresh facts of considerable importance towards a more complete knowledge of the early history of dicotyledonous plants.

In addition to his numerous papers on palæobotany, Saporta has left such works as 'Le Monde des Plantes avant l'Apparition de l'Homme,' 'Origine paléontologique des Arbres cultivés ou utilisés par l'Homme,' and, in collaboration with Prof. Marion, 'L'Évolution du Règne végétal'; these form fitting memorials of his wide knowledge as a palæobotanist, and of his zealous advocacy of the importance of fossil forms to the student of plant-evolution. By some readers Saporta is perhaps best known as the too eager upholder of the claims of certain structureless casts and impressions to be included among fossil algæ. The valuable contributions to this subject by Nathorst have clearly shown how little weight must be attached to any speculations as to the development of plant-life based on Saporta's 'Algues fossiles' or his 'Organismes problématiques des anciennes Mers.'

As a contributor to Tertiary and Mesozoic botany, Saporta's name will always be associated with that of Heer and Ettingshausen;

and the later generation of workers in this branch of palæontology may well look upon him as a worthy pupil of Adolphe Brongniart, whose philosophic spirit and scientific handling of facts are reflected in the writings of his younger countryman. The writer of a recent obituary notice in a French scientific journal has thus happily expressed Saporta's unfailing industry: 'À des travaux considérables succédaient des entreprises plus considérables encore, et l'on oubliait l'âge en voyant l'œuvre s'augmenter et les horizons s'étendre toujours.'—[A. C. S.]

John Whitaker Hulke, F.R.S., President of the Royal College of Surgeons of England: Foreign Secretary of the Geological Society of London.

Only four days after the Anniversary Meeting last year, in the plenitude of his honours, and in the faithful discharge of his duties for the alleviation of suffering humanity, our late Foreign Secretary gave up his life. As senior surgeon he was summoned to Middlesex Hospital to perform an operation on February 7th, one of the most terribly severe nights of that exceptionally trying month; he returned home, fatigued and suffering from bronchitis, at 3.30 A.M., but attended and operated at the hospital on the 9th; visited his patients again on the 10th and 11th, when serious illness prostrated him, and he succumbed on the 19th February to pneumonia.

John Whitaker Hulke was born on November 6th, 1830, being the elder son of a well-known and widely respected general practitioner at Deal. The original family name was Hulcher, his ancestors being Dutch by origin, who had escaped from Holland during the Spanish persecutions under Philip II. and Ferdinand, Duke of Alva, and settled on the Kentish coast. There for some two hundred years they have followed the vocation of medicine. He was educated at King's College School, and at Neuwied, in Germany, and at the age of nineteen entered the medical school of King's College, where he was a dresser to Mr. (afterwards Sir) William Bowman, and house-surgeon to Sir William Fergusson. It was while he occupied this position that he attended the Duke of Wellington in his last illness, his father being the Duke's regular medical attendant and obtaining leave to avail himself of his son's services as assistant. In 1854, when the Crimean War broke out, he was early to volunteer, and at the beginning of 1855 was appointed assistant surgeon to the British Civil Hospital at Smyrna. Thence he was sent to Sebastopol, and in that awful campaign of

irremediable sickness, gross mismanagement, and gallantry as often as not ineffective, bore himself, in the opinion of everyone, with patient courage as a brave soldier.

On his return from the East he became medical tutor of King's College Hospital, and, having previously been elected a Fellow of the Royal College of Surgeons of England, was appointed, in 1858, assistant surgeon to Moorfields Hospital. He had previously been elected assistant surgeon to King's College Hospital, where, having duly served his allotted period, he was appointed, together with Dr. Charles Murchison, a colleague at King's, to the Middlesex Hospital, of which institution he was the senior surgeon at the time of his death.

Mr. Hulke's earliest mark was made in ophthalmology. He obtained the Jacksonian Prize of the Royal College of Surgeons of England for an essay on the Morbid Changes of the Retina; his treatise on the Use of the Ophthalmoscope (1861) formed an excellent introduction for most of the profession to the new system of intraocular examination; his Arris and Gale Lectures, delivered before the Royal College of Surgeons, and subsequently published, dealt with the Minute Anatomy of the Eye.

Mr. Hulke was elected a Fellow of the Royal Society in 1867, his claim being based exclusively on researches relating to the anatomy and physiology of the retina in man and the lower animals, particularly in the reptiles. These were embodied in two papers in the 'Philosophical Transactions' ('On the Anatomy of the *Fovea centralis* of the Human Retina,' and 'On the Chameleon's Retina'), and in a paper on the 'Retina of Amphibia and Reptiles,' in the first volume of the 'Journal of Anatomy and Physiology.' These are characterized by patient and conscientious minuteness in the working out and description of details, and cautious reserve in drawing inferences. Probably the most important and permanently valuable of Mr. Hulke's researches were those relating to the Retina of the Chameleon, which the abundant material at his disposal enabled him to elaborate in a more complete manner than had before been possible.

Mr. Hulke served on the Council of the Royal Society during 1879, 1880, 1888, and 1889; and was also a Member of the Scientific Relief Committee. His communications to the Transactions of that Society were numerous, and the last of them was read before it on May 12th, 1892—'On the Shoulder-girdle in Ichthyosauria and Sauropterygia.'

Very soon after he became a Fellow of the Royal Society Hulke

transferred his allegiance to geology, between which and his profession as a consulting surgeon his energies were thenceforth to be divided. Had he continued his anatomical studies he would without doubt have attained to the foremost rank among physiological anatomists.

During the quarter of a century which followed his first contributions to geological science, Mr. Hulke found leisure to apply himself to research in this field, notwithstanding his constantly increasing practice. He did so to so good a purpose that he became a palæontologist of no ordinary merit. His knowledge of comparative anatomy, and especially of osteology, enabled him rapidly to grasp the meaning of structures presented by the remains of fossil vertebrates; and this, combined with a naturally keen perception and a rigid adherence to facts, soon caused his opinion on palæontological matters to be sought, and held in the highest estimation.

It was the fossil Reptilia which more especially occupied Hulke's attention, and his numerous papers on their osteology are a monument to his industry. Many of the fossils which he described were, in part at least, freed from the matrix by his own facile chisel; and in this mechanical work, as he himself has said, he often found relaxation when his mind was overwrought by professional anxieties.

Mr. Hulke's well-earned vacations were often spent at localities of geological interest, more especially with a view to working out the fossils which might be obtained. For this purpose he paid frequent visits to Brook, in the Isle of Wight, whence have come many specimens of Wealden Dinosauria; near here also, at Brixton, was preserved the unique collection of these Wealden reptiles, made by the Rev. W. Fox. For many years Mr. Hulke was the only palæontologist who had free access to this collection; and he did much good work in bringing to light its hidden treasures, which would otherwise have remained almost unknown until after the death of the owner, when they were acquired by purchase for the British Museum.

In the year 1868, Mr. Hulke was elected a Fellow of the Geological Society of London, and from that time onwards the pages of the 'Quarterly Journal' of that Society were frequently enriched by his writings. No fewer than six of his papers were published in the two volumes which followed the year of his election, and these, with one exception, were descriptions of Saurian remains from the Kimmeridge Clay of Dorset. Several other papers on reptiles from the

same locality appeared in subsequent volumes; but Mr. Hulke was more particularly interested in the Dinosauria, and many contributions to the osteology of this interesting group of reptiles have appeared in the 'Quarterly Journal' of the Geological Society, and in the 'Philosophical Transactions' of the Royal Society.

Our first knowledge of the cranium of *Iguanodon* was due to Mr. Hulke's work upon a specimen from the Isle of Wight, which completely revealed the brain-cavity, but, as it did not include the facial bones, its affinities were by no means easy to determine.

In 1873 and 1874 Mr. Hulke made additions to our knowledge of the small Wealden Dinosaur, which had been named by Professor Huxley *Hypsilophodon Foxii*; and in 1882 a still more important memoir on the same species was published in the 'Philosophical Transactions.'

In 1874 and 1876 he showed that a certain bone of *Iguanodon*, which had been regarded as a scapula, was really a part of the pelvis; and, indeed, it proved to be the remarkable pubis of that reptile, which so nearly resembles that of a bird.

In 1879 the two genera, *Poikilopleuron* and *Megalosaurus*, were proved by him to be one and the same Dinosaurian genus. In the same year he described the remains of a new Wealden Dinosaur under the name of *Vectisaurus valdensis*; and in 1880 he made known one of the most perfect Iguanodons discovered in this country, obtained by Prof. (now Sir) Joseph Prestwich, from the Kimmeridge Clay of Cumnor, which he named *Iguanodon Prest-*

In the following year there appeared in the 'Philosophical Transactions' Mr. Hulke's memoir on *Polacanthus Foxii*. This remarkable Dinosaur, the name for which had been suggested by Sir R. Owen, has a broad dermal shield spread out above the iliac bones in such a way as to form a kind of carapace over the lumbar and sacral regions; besides this, large spines and scutes were attached to other parts of the animal's body.

Mr. Hulke's presidential addresses to the Geological Society, 1883–84, formed an important contribution to our knowledge of reptilian osteology, and especially threw light on the structure of the shoulder-girdle in Plesiosaurs and their allies.

The Iguanodont-remains found in England have been more or less fragmentary, and discoveries made by other workers which might serve to elucidate their structure were always hailed by Mr. Hulke with extreme satisfaction. No one more heartily

rejoiced than he did when the geologists of Belgium made known the discovery of the series of magnificently perfect *Iguanodon* skeletons, a facsimile of one of which now adorns the Museum of Natural History in Cromwell Road.

Mr. Hulke served for many years on the Council of this Society, and the high esteem in which he was held by the leading geologists of the day, as well as the thorough appreciation of his palæontological work, found expression by their electing him, in 1882, to fill the Presidential chair of this Society, and, in 1887, by presenting him with the Wollaston Gold Medal, the greatest honour that it was in the power of the Council to bestow. In 1891 he was elected Foreign Secretary of the Geological Society, which office he still held at the time of his decease.

Mr. Hulke left behind him a large series of most valuable specimens, mostly of Dinosauria, obtained with his own hands from the Undercliff in the Isle of Wight. This collection has been presented to the British Museum (Natural History) by Mrs. Hulke, in memory of her husband.

Lieutenant-General R. F. Copland-Crawford, R. A., was elected a Fellow of the Geological Society of London in 1875, and died at his residence, Sunbury Lodge, near Wembley, Harrow, on March 5th, 1895, in his 85th year.

He was for many years a constant attendant at the Anniversary Meetings of the Palæontographical and Geological Societies, and his handsome, tall figure, military bearing, and his graceful method of proposing resolutions on such occasions will be remembered by many Fellows. He was not a writer, but a reader of geological literature.

Sir Edward Herbert Bunbury, Bart., was born in 1811, and educated at Trinity College, Cambridge, where, in 1833, he graduated B.A. (was senior classic and Chancellor's Medallist), and M.A. in 1836. Five years later he was called to the Bar of the Inner Temple, and was M.P. for Bury St. Edmunds from 1847 to 1852. He was elected a Fellow of the Geological Society in 1837, but does not appear to have communicated any paper to the 'Quarterly Journal.' Sir Edward Bunbury brought out his 'History of Ancient Geography' in 1879, and was a contributor to Sir William Smith's 'Dictionaries of Greek and Roman Biography and Geography,' especially the latter. He died on March 5th, 1895, in his 84th year.

ROBERT FITCH, F.S.A.—Geology, like other branches of Natural History, has owed much of its progress to the zeal of collectors. Of these, one of the most painstaking and successful was the late Robert Fitch, who, in addition to a most valuable collection of antiquities, had gathered together a very fine series of fossils from the Crag and Chalk of Norfolk. He was born at Ipswich, on October 21st, 1802, educated at the Grammar School, and apprenticed to a chemist and druggist in the town. Pursuing this occupation he settled at Norwich, in 1827, in partnership with Mr. Sheriff Chambers, and continued until he was over 90 years of age to take an active interest in business. From an early date he took great pleasure in fossils, and his specimens were always at the service of those engaged in palæontological studies.

He seldom wrote on geological subjects, his chief literary contributions being to the 'Transactions of the Norfolk Archæological Society.' In 1836, however, he communicated to the Geological Society an account of the discovery of the tooth of a *Mastodon* in the Crag at Thorpe, near Norwich; and in 1840 he sent to the 'Magazine of Natural History' a 'Notice of the existence of a distinct Tube within the hollows of the Paramoudra.' In later years he announced before the Norwich Geological Society the finding of Deer's antlers in re-deposited Chalk at Hartford Bridges, near Norwich; and also the discoveries of Flint Implements in the valley of the Little Ouse.

His fine collection is placed in a special room in the new Museum buildings at Norwich Castle. He died on April 5th, 1895, in the 93rd year of his age.

JAMES DWIGHT DANA was born in Utica, New York, on February 12th, 1813, and was educated at Yale College, where he graduated in 1833. On leaving Yale, he entered the service of the United States Navy as teacher of mathematics to midshipmen. In this capacity he visited, on board the 'Delaware' and the 'United States,' a number of the seaports of France, Italy, Greece, and Turkey, the cruise lasting fifteen months.

In 1836 he became assistant to Prof. Benjamin Silliman, the mineralogist, and in 1837 he published his 'System of Mineralogy,' a work which obtained a worldwide reputation, and which ran through numerous editions, of which the last was issued in 1892. Dana was next appointed Geologist to the Wilkes Exploring Expedition, which sailed in 1838, and returned in 1842. The

expedition consisted of five ships, the route pursued being briefly as follows:—First to Madeira, then to Rio Janeiro, down the coast and through the Straits of Magellan, after passing which, while on board the 'Relief,' he nearly suffered shipwreck off Noir Island, the ship remaining for three days and nights in extreme peril; in the same storm one of the smaller accompanying vessels was lost. Thence they sailed to Chili, Peru, and across to the Paumotus, to Tahiti, and the Navigator Islands; then to New South Wales, where the naturalists remained while Commodore Wilkes went into the Antarctic region; then to New Zealand and the Fiji Islands, where two of the officers were murdered by the natives; thence to the Sandwich Islands, the Kingsmill group, the Caroline Islands, and north to the coast of Oregon. Here, near the mouth of the Columbia river, the 'Peacock,' the ship to which Dana had been assigned, was wrecked, entailing the loss of all his personal effects, as well as many of his collections. He then made one of the party that crossed the mountains near Mount Shasta, and found their way down the Sacramento river to San Francisco. In his report of the expedition he states that the geological features indicated the probable presence of gold. This was six years before the discovery of gold in California, and rich mines have since been discovered in the region over which the party went. At San Francisco they were taken on board the 'Vincennes' and the homeward voyage was made by way of the Sandwich Islands, Singapore, the Cape of Good Hope, and St. Helena, arriving in New York in June, 1842. As a result of his connexion with the expedition he published the Reports on Geology, Crustacea, and Zoophyta, and spent in all thirteen years editing and superintending the printed reports resulting from these voyages. In 1855 he succeeded to the Chair of Mineralogy at Yale, a position which he held till 1894, when he resigned. His 'Manual of Geology' appeared in 1863, a fourth edition having been issued only last year, 1895. He was part editor of the 'American Journal of Science' from 1846, and continued his interest in it up to the last.

Dana received the Copley Medal from the Royal Society in 1877, and the Wollaston Medal from the Geological Society in 1872; he was a member of the Academy of Sciences, Paris, and of the Academies of Berlin and Munich. Moreover, he was elected a Foreign Member of the Royal Society in 1884, and of the Geological Society in 1851.

His publications amount to nearly 400 in number, and when one

considers that these include such colossal works as his 'Mineralogy' and his 'Manual' and 'Text-book of Geology,' one is astonished at Prof. Dana's wonderful power of work, nor is one surprised to learn that his health broke down upon several occasions owing to his excessive mental labours. It is extremely touching to read of Prof. Dana working on at the new edition of his 'Manual of Geology' at the age of 82, and being actively assisted in all his literary labours by his life-long companion with never-failing and watchful care to the end.

It is impossible to do justice to this distinguished man and personal friend in so short a notice, but we feel that, with our American brethren, we have lost in him one of the greatest figures in geology of our time. Prof. Dana died on April 14th, 1895, in his 82nd year.

It is hardly credible that a man could have attained to so high a position at once in zoology, in mineralogy, and in geology, and, from the specialization now rendered necessary by the progress of natural knowledge, we cannot expect to look upon his like again, nor to see united in one man attainments so varied in character as were those of the American veteran, James Dwight Dana.

As a man, he was noted for the gentleness and kindness of his character, so that he was always on excellent terms with all his colleagues. He leaves a widow and four sons and daughters.

Mr. Joseph Mitchell, Jun., Assoc.M.Inst.C.E., was born on September 7th, 1840. He was distinguished as a colliery engineer in the South Yorkshire district, several of the largest mines in the Barnsley district having been either sunk or re-opened by him. Among the latter may be noticed the Swaithe Main and Edmund's Main Collieries, re-opened and put in order after explosions, and of the former the Mitchell Main Colliery. A more important enterprise for the development of 2500 acres of the Barnsley bed at Grimesthorpe was commenced about six months before his death. Both as Secretary and President he contributed largely to the development of the Midland Institute of Mining, Civil, and Mechanical Engineers, and he was also very active in the formation of that most useful body, the Federated Institution of Mining Engineers. He was elected a Fellow of the Geological Society in 1873. His death occurred on April 18th, 1895.

VALENTINE BALL, C.B., M.A., and LL.D. (Dublin), F.R.S., M.R.I.A., Director of the National Museum at Dublin, was the second son of the well-known naturalist, Dr. Robert Ball, who died in 1857. His elder brother is Sir Robert Ball, of Cambridge, and his younger brother is Dr. Charles B. Ball, of Merrion Square, Dublin. Dr. Valentine Ball was born on July 14th, 1843, at No. 3 Granby Row, Dublin, a house well known in those days as a leading centre of intellectual resort in that metropolis. He was educated first at a private school by Dr. Brindley at Chester, and afterwards by Dr. Benson, in the early days of Rathmines School.

Valentine Ball entered Trinity College in 1860, and about the same time he was appointed by the later Master Fitzgibbon to a clerkship in the office of the Examiner in Chancery. His University career was not an eventful one in the academic sense, for the duties of his office in the Four Courts did not leave him sufficient time for more than obtaining an ordinary degree. A taste for scientific pursuits was, however, so marked that in 1864, when he was twenty-one years of age, he was appointed to the Geological Survey of India, then under the direction of Dr. Thomas Oldham. Ball felt that this would give him the opportunity which he wanted for the study of nature in a wide field, and accordingly he went to India. His duties as a geological surveyor often led him into very unfrequented parts of our Oriental possessions, and frequently, for many months together, he lived in camp in the jungle, apart from all other Europeans. Wherever Ball travelled he utilized his opportunities to the utmost; indeed, throughout his life, his diligence could hardly have been surpassed, and nothing worthy of notice that came within his range was unobserved and unrecorded. It was presently apparent that the young geological surveyor was not only able to fulfil his duties in making a careful investigation of the rocks and of their economic value, but that various other branches of natural history were sedulously cultivated by him.

Steadily the reputation of the Indian geologist advanced in scientific circles. He was elected a Fellow of the Calcutta University in 1872. He devoted a short vacation to extending his travels to the Andaman and Nicobar Islands, and to visiting Barren Island and Narcondam volcanoes in the Bay of Bengal, which he described in the 'Geological Magazine,' 1879, p. 16, pl. i.; 1888, p. 404; and 1893, p. 289, pl. xiii.

In 1874 Valentine Ball was elected a Fellow of the Geological Society of London. His first important volume, 'Jungle Life in

India,' gives a record of his travels and summarizes the results of his numerous papers. This work was followed by an elaborate treatise on the economic geology of India. His scientific reputation had by this time become so firmly established that, on the resignation of the Chair of Geology in the University of Dublin by the Rev. Dr. Haughton, Valentine Ball was appointed his successor. Thus was brought to a close his connexion of seventeen years with the Geological Survey of India.

In 1882 he was elected a Fellow of the Royal Society. In September 1883, Ball was appointed Director of the Science and Art Museum in Dublin, and resigned his Professorship in the University for the coveted post of Custodian of the new Museum, which he so ably and admirably organized, and to which he devoted the remainder of his life with unsparing energy and zeal.

Though his death was premature, yet it may be said that he had lived long enough to see the substantial completion of his life's task, the arrangement of the new Museum, which will long remain as a testimony to his work.

The University of Dublin conferred on him the honorary degree of Doctor of Laws, and by Her Majesty he was made a Companion of the Bath. With most of the scientific societies of Dublin Dr. V. Ball was in intimate association.

In 1879, he married the eldest daughter of the late John Stewart Moore, of Moyarget, Co. Antrim. He leaves a family of four young children. For some years Dr. Ball's health had been failing. Towards the middle of June serious symptoms became apparent, and he passed away peacefully on the afternoon of June 15th at his residence, 28 Waterloo Road, Dublin.

The only communications which Valentine Ball made to the Geological Society were 'On the probable Mode of Transport of the Fragments of Granite and other Rocks which are found embedded in the Carboniferous Limestone of the neighbourhood of Dublin,' Quart. Journ. Geol. Soc. vol. xliv. (1888) p. 371; and 'On some Eroded Agate-pebbles from the Soudan,' Quart. Journ. Geol. Soc. vol. xliv. (1888) p. 368.

In the Right Hon. Thomas Henry Huxley, this Society has lost one of its most distinguished Fellows, and the world of science one of its brightest ornaments.

He was elected a Fellow in 1856, was placed upon the Council in 1858, and in the same year was chosen to be one of the Secretaries,

filling that office till 1862. In that year, owing to the absence from England of the then President, Mr. Leonard Horner, Mr. Huxley drew up and delivered the customary Anniversary Address. He was a Vice-President in 1866; filled the office of President of the Society in 1868–69, and was again a Vice-President in 1871.

His first paper was read before the Society as early as 1856, and his last (on *Hyperodapedon Gordoni*) on May 11th, 1887, a period of 31 years, during which time he communicated 25 separate papers and three Presidential Addresses.

In 1876 the Society awarded him the blue-ribbon of our science, the Wollaston Medal.

Such is the record which Huxley has left us within these walls; but the energies he possessed, and the genius which inspired him, carried him into many other fields, and we cannot claim for ourselves more than a share in the life-work of this gifted and brilliant naturalist and scholar.

Thomas Henry Huxley was born at Ealing on May 4th, 1825, and was for some years educated at the School in his native place, where his father was one of the masters. This preparatory course was followed by assiduous private reading, including German scientific literature, and instruction in medicine received from a brother-in-law, who was a physician. He afterwards attended lectures at the Medical School of the Charing Cross Hospital. In 1845 he passed the first M.B. examination at the University of London, taking honours in anatomy and physiology. Even before this he had given evidence that his mind was occupied with something more than the technical details of the medical profession, for, while yet a student at Charing Cross Hospital, he had sent a brief notice to the 'Medical Times and Gazette' of that layer in the root-sheath of hair which has since borne the name of Huxley's Layer. After devoting himself for a short time to the practice of his profession among the poor of London, he, in 1846, joined the medical service of the Royal Navy, and was sent to Haslar Hospital. Here he did not remain long, but, like so many other men who have made their mark in biological science, set out on a voyage round the world.

Through the influence of the distinguished naturalist, Sir John Richardson, who had accompanied Franklin in his early Arctic expeditions, young Huxley obtained the post of assistant-surgeon on Her Majesty's ship *Rattlesnake*, then about to proceed on a surveying voyage to the Southern Seas. The ship sailed from England in the winter of 1846, and did not return until November,

1850. During the greater part of that time the *Rattlesnake* was employed in surveying the eastern and northern coasts of Australia and the coast of New Guinea. The seas lying between the Great Barrier Reef and the coast of the mainland were of special interest to the naturalist. Huxley took ample advantage of his opportunities to study the fauna of the seas which he traversed, with the results known to all naturalists. The communications which he sent home during the voyage made his name well known to the scientific world even before his return. Several of these were published in the 'Philosophical Transactions' of the Royal Society, and it is interesting to note that his first paper was presented to the Society by the then Bishop of Norwich (father of Capt. Owen Stanley, R.N., who commanded the *Rattlesnake*), and read June 21st, 1849: 'On the Anatomy and Affinities of the Medusæ.' Huxley in vain endeavoured to obtain the publication by the Government of a part of the work done during his voyage, and it was not until 1859 that his great work, entitled 'Oceanic Hydrozoa, a description of the Calycophoridæ and Physophoridæ observed during the voyage of Her Majesty's ship *Rattlesnake*, was given to the world.

The reputation which he had already attained at the early age of 26 is evident from the fact that in the year after his return, 1851, he was elected a Fellow of the Royal Society, and in 1852 was awarded one of the Society's Royal medals. In 1853 he left the Naval Service, and the following year, on the removal of Edward Forbes from the Royal School of Mines to the Chair of Natural History in Edinburgh, Huxley was appointed Professor of Natural History, including Palæontology, in that institution, a post which he held until his retirement at the age of 60—an age at which, as he was wont to assert, every scientific man ought to commit the happy despatch. In the same year, 1854, he was appointed Fullerian Professor of Physiology to the Royal Institution and Examiner in Physiology and Comparative Anatomy to the University of London. Other posts and honours crowded thick upon him. From 1863 to 1869 he held the Chair of Hunterian Professor at the Royal College of Surgeons. In 1862 he was President of the Biological Section at the Cambridge Meeting of the British Association, and eight years later held the Presidency of the Association at the Liverpool Meeting. In 1869 and 1870 he was President of the Geological and Ethnological Societies. As might be expected, Prof. Huxley held strong and well-defined views on the subject of education. He was a man who at all times had a keen sense of public duty, and it was

this which induced him to seek election on the first London School Board in 1870. Ill-health compelled him to retire from that post in 1872, but during his period of service as Chairman of the Education Committee he did much to mould the scheme of education adopted in the Board Schools.

He was elected Secretary of the Royal Society in 1873, and ten years later was called to the highest honorary position which an English scientific man can fill, the Presidency of that Society. During the absence of the late Prof. Sir Wyville Thomson with the 'Challenger' Expedition, Huxley, in 1875 and 1876, took his place as Professor of Natural History in the University of Edinburgh. From 1881 to 1885 he acted as Inspector of Salmon Fisheries. But this and all his other official posts he resigned in 1885, shortly after which he removed to Eastbourne.

During the 34 years that elapsed between his return from the 'Rattlesnake' voyage and his retirement from his various official posts, Huxley's activity as an investigator, as a writer, as a lecturer, as a citizen of London and of England, and as a man of healthy social instincts was incessant. There is hardly a department in the wide field of zoology, in its most comprehensive sense, in which he has not done original work. Huxley's investigations have explained many difficult problems in the mechanism of men and animals. So far as the character of his work is concerned, he is to be compared rather with Owen than with Darwin; though not only was the quality of his work more solid and enduring, but in many ways his type of mind was essentially different from that of Owen, more liberal, more open, free from what may perhaps be called the pettiness which hampered Owen's scientific vision. Huxley's investigations, it may fairly be said, especially after the publication of the 'Origin of Species,' were to a large extent guided by the Darwinian theory, and the results may be regarded as among the most substantial confirmations and illustrations of the doctrine of evolution as propounded by Darwin.

In the year before the publication of the 'Origin' he chose as the subject of his Royal Society Croonian Lecture 'The Theory of the Vertebrate Skull,' in which, so high an authority as Prof. Hæckel assures us, he first opened out the right track to a solution of a perplexing problem. Much of Huxley's technical work was published through the Royal Society, the Geological Survey, the Geological Society, and other media familiar to specialists, but seldom consulted—even by the educated general public. To give a mere list of these many memoirs would serve no purpose. Such important

subjects are dealt with as the Evolution of the Crocodilia, the Classification of Birds, the Dinosauria, Fossil Fishes, *Glyptodon*, the Affinity between Reptiles and Birds, *Ceratodus*, the Cranial and Dental Structure of the Canidæ, Reproduction and Morphology of *Aphis*, the Development of *Pyrosoma*. These few from among the titles of many memoirs will suffice to show that Huxley's special researches deal with the history and structure of animals of many types, and that by themselves they would justify the verdict of Ernst Hæckel that Huxley was the first zoologist among his countrymen. In this connexion may be mentioned his 'Manual of the Invertebrata,' his 'Lessons in Elementary Physiology,' and other text-books. 'When we consider the long series of distinguished memoirs with which,' to quote Hæckel, 'Prof. Huxley has enriched zoological literature, we find that in each of the larger divisions of the animal kingdom we are indebted to him for important discoveries. . . . More important than any of the individual discoveries which are contained in Huxley's numerous less and greater researches on the most widely different animals, are the profound and truly philosophical conceptions which have guided him in his enquiries, have always enabled him to distinguish the essential from the unessential, and to value special empirical facts chiefly as a means of arriving at general ideas.'

Huxley had a power of popular exposition almost unequalled. He could make plain, even to an ordinary working-man audience, the bearings of the most recondite researches of the zoologist and botanist; witness his famous Norwich lecture 'On a Piece of Chalk,' and the memorable sermon which he gave on a Sunday evening a quarter of a century ago in the midst of shocked Edinburgh. But it is not only to the ordinary intelligent reader that his numerous lectures, addresses, and magazine articles appeal. It is to these in their collected form that the special enquirer must go to find the broad results of Huxley's arduous scientific investigations. It was his duty when first he assumed his post in the School of Mines to give a course of lectures every alternate year to working men; and it was through this channel that he first made known his remarkable discussion on 'Man's Place in Nature.' This was one of the earliest and one of the most striking results of the publication of the Darwinian theory, for it was given to the world some ten years before the issue of Darwin's 'Descent of Man.' Even by those who maintain that influences have been at work in the development of Man, additional to those which have

been common to him and the lower animals, it may be said that Huxley's conclusions as to the intimate relations between humanity and the higher apes have been generally accepted. It was in the same 'popular' form that Huxley gave to the world many other theories and disquisitions which have had much to do with moulding educated opinion during the last quarter of a century. Thus in his three addresses as President of the Geological Society: on 'Geological Contemporaneity and Persistent Types of Life,' on 'Geological Reform,' and on 'Palæontology and the Doctrine of Evolution,' he dealt in his characteristically clear and masterly manner with problems that still agitate evolutionists—the imperfection of the record, the duration of geological time, the succession of life on the face of the earth, and other matters of profound interest to geologists and biologists. In his papers on 'The Methods and Results of Ethnology' and on 'Some Fixed Points in British Ethnology' he introduced into the somewhat chaotic branch of investigation that deals with Man a simplicity of treatment and a scientific method which have done much to raise it above a mere collection of unrelated facts. The lectures delivered in America in 1876 brought together the data as to the evolution of the Horse with a cogency that forms one of the most telling arguments in favour of the Darwinian hypothesis.

The only posts which Huxley continued to fill up to the time of his death were those of Dean and Honorary Professor of Biology in the Royal College of Science, South Kensington, Trustee of the British Museum, and President of the Palæontographical Society of London. In 1892 he was admitted a member of the Privy Council, having previously refused the honour of knighthood.

It is impossible to enumerate here the many honours conferred upon Prof. Huxley. He was made a Doctor of the Universities of Edinburgh, Dublin, Cambridge, Oxford, Breslau, and Würzburg. The Academies of Brussels, Stockholm, Copenhagen, Cairo, Berlin, Göttingen, Haarlem, St. Petersburg, Lisbon, Rome, Munich, Philadelphia, and many others, conferred on him their diplomas. He was made an Honorary Fellow of the Royal Society of Edinburgh; a Member of the Royal Irish Academy; of the American Academy of Science; and (in 1879) a Corresponding Member of the Institute of France (Section Anatomy and Zoology, in place of Von Baer). He was also a Knight of the Polar Star of Sweden.

Turning to his published works, we may refer to his 'Oceanic Hydrozoa'; his 'Lectures on Comparative Anatomy and Physiology';

'Lessons in Elementary Physiology' (1866), and many subsequent editions; 'An Introduction to the Classification of Animals' (1869); 'Lay Sermons, Addresses, and Reviews' (1870). His text-books on the Anatomy (I.) of the Vertebrata (1871) and (II.) of the Invertebrata; his 'Practical Biology'; 'Man's Place in Nature'; his works on the Crayfish, and on Physiography, well illustrate the wide extent and versatility of his powers, both as a naturalist and author; but it was by his lectures and addresses that he displayed the most marvellous of his intellectual gifts, and produced the greatest effect upon the science of his time. He had that wonderful power of carrying his audience along with him, and the happy facility of bringing his knowledge within the mental grasp of his hearers.

Of the 144 papers attributed to Prof. Huxley in the Royal Society's list of scientific papers extending from 1847 to 1884, the following may be mentioned as directly connected with our own science:—

On the Method of Palæontology (Annals, 1856). *Pygocephalus Cooperi*, a Coal-measure Crustacean (Q. J. G. S. 1857). On the genus *Pteraspis* (Brit. Assoc. Rep. 1858). On *Cephalaspis* and *Pteraspis* (Q. J. G. S. 1858). On *Plesiosaurus Etheridgei* (Q. J. G. S. 1858). On Persistent Types of Animal Life (Roy. Inst. Proc. 1858–62). On Species and Races and their Origin (Roy. Inst. Proc. 1860). On *Stagonolepis Robertsoni* (Q. J. G. S. 1859). On some Amphibian and Reptilian Remains from South Africa and Australia (Q. J. G. S. 1859). On *Dicynodon Murrayi*, South Africa, and on Skulls of Dicynodonts (Q. J. G. S. 1859). On *Rhamphorhynchus Bucklandi*, a Pterosaurian from Stonesfield (Q. J. G. S. 1859). On a Fossil Bird and a Fossil Cetacean from New Zealand (Q. J. G. S. 1859). On Dermal Armour of *Crocodilus Hastingsiæ* (Q. J. G. S. 1859). On the Anatomy of *Pterygotus* (Geol. Surv. Mem. 1859). On *Dasyceps Bucklandi* (Geol. Surv. Mem. 1859). On the Lower Jaw of a Labyrinthodont (Geol. Surv. Mem. 1859). On *Macrauchenia boliviensis* (Q. J. G. S. 1861). On *Pteraspis dunensis* (Q. J. G. S. 1861). Systematic Arrangement of Devonian Fishes (Geol. Surv. Mem. 1861). New Labyrinthodonts from Edinburgh Coal-field (Q. J. G. S. 1862). On a Stalk-eyed Crustacean from the Coal-measures, Paisley (Q. J. G. S. 1862). On the Premolar Teeth of *Diprotodon* (Q. J. G. S. 1862). On a New Species of *Glyptodon* (Roy. Soc. Proc. 1862–63). *Anthracosaurus Russelli*, Coal-field, Lanark (Q. J. G. S. 1863). On Cetacean Fossils termed '*Ziphius*,' Cuvier, from the Red Crag (Q. J. G. S. 1864). Osteology of *Glyptodon* (Phil. Trans. 1865). Vertebrate Remains from Jarrow Colliery, Kilkenny, Ireland (Geol. Mag. 1866). Dinosaurian Reptiles from South Africa (Q. J. G. S. 1867). On *Acanthopholis horridus*, a new Reptile from the Chalk Marl (Geol. Mag. 1867). New Specimen of *Telerpeton elginense* (Q. J. G. S. 1867). Animals intermediate between Birds and Reptiles (Geol. Mag. 1868). Two new Fossil Lacertilians from South Africa (Geol. Mag. 1868, pp. 201–205). On *Archæopteryx lithographica* (Roy. Soc. Proc. 1868). On *Hyperodapedon* (Q. J. G. S. 1869). On a new Labyrinthodont, *Pholiderpeton scutigerum*, from Bradford (Q. J. G. S. 1869). On the Upper Jaw of *Megalosaurus* (Q. J. G. S. 1869). Principles and Methods of Palæontology (Smithsonian Reports, 1869). The Milk-Dentition of *Palæotherium magnum* (Geol. Mag. 1870). On *Hypsilophodon Foxii*, a new Dinosaurian from the Wealden, Isle of Wight (Q. J. G. S. 1870). Further

Evidence of the Affinity between the Dinosaurian Reptiles and Birds (Q. J. G. S. 1870). On the Classification of the Dinosauria, with Observations on the Dinosauria of the Trias (Q. J. G. S. 1870). Triassic Dinosauria ('Nature,' 1870, p. 23). On the Maxillæ of *Megalosaurus* (Phil. Mag. 1870). (With Dr. E. P. Wright) On the Fossil Vertebrata from the Jarrow Colliery, Kilkenny, Ireland (Roy. Irish Acad. Trans. 1871). On *Stagonolepis Robertsoni*, etc. (Q. J. G. S. 1875). On the Evidence as to the Origin of existing Vertebrate Animals (lectures, 'Nature,' 1876). The Rise and Progress of Palæontology ('Nature,' no. 24, 1881). The Coming-of-age of the 'Origin of Species' (1880, Roy. Inst. Proc. 9, 1882).

It may be truly said of Huxley that, although an antagonist to be feared, and a vigorous hater of all shams, he was also a warm-hearted and staunch friend, and one who never forgot a service rendered to him. The influence of his writings and his scientific labours will long outlive the memory of those who now mourn his loss.

Charles Cardale Babington, M.A., F.R.S., Fellow of St. John's College, Cambridge, was born on November 23rd, 1808, at Ludlow. He was a student at St. John's College, Cambridge, and graduated in 1832. In 1861 he succeeded Prof. Henslow in the Chair of Botany at the University. He retained his professorship until his death, on July 22nd, 1895, but for the later years of his life ceased to take an active part in the work of the Botanical School. Prof. Babington attained to the highest position as a critical British botanist, having an intimate and accurate acquaintance with the flora of our islands, and was the first to carefully correlate it with that of Europe.[1]

The best testimony of the value of his work is the fact that his 'Flora' has passed through eight editions in his lifetime, and still remains a standard work. In fossil botany his only contributions are the determination of some plants from the peat of Cambridgeshire.

He published 'A History of the Chapel of St. John's College, Cambridge,' and contributed many papers to the publications of the Cambridge Antiquarian and other Societies.

He was elected a Fellow of the Geological Society in 1835, but never contributed any paper to its Quarterly Journal.

Thomas James Slatter, whose decease we have now to record, died at his house, 'The Drift,' Evesham, on August 1st, 1895, in his 61st year. He was a geologist whose knowledge of the locality

[1] See Babington's 'Manual of British Botany'; the first edition appeared in 1843, and the eighth in 1881.

in which he lived and worked was most intimate and reliable. He was born at Gloucester in 1834, while his family was for many years located at Stratton, near Cirencester. He was the cousin and intimate friend of John Jones, of Gloucester, whose contributions to geological literature are well known. Mr. Slatter commenced his business life, when quite a young man, in the Gloucestershire Bank, and then took up his abode at Evesham. He became successively manager of the Moreton-in-the-Marsh, Redditch, and Evesham branches of the Bank, but retired into private life a few years since, and, having erected a house on Green Hill, near Evesham, he removed thither his extensive and most interesting collection of Liassic fossils. In 1879 he became a Fellow of the Geological Society, but, to the regret of those who knew how careful an observer he was, he never became the author of any work on geology, nor even of any contribution to a periodical on the geology of the district which he knew so well.

George Francis Hosking, who resided at Bendigo, Otago, New Zealand, was elected a Fellow in 1891. He died at Dunedin, New Zealand, August 18th, 1895. He had not contributed any paper to the Society.

By the death of Mr. James Carter, F.R.C.S., which took place at Cambridge on August 31st, 1895, in his 82nd year, one of the few remaining links which connected the days of Sedgwick with those of the modern school of geology in Cambridge has been broken. During the greater part of his life Mr. Carter practised as a surgeon in Cambridge, where his house, in Petty Cury, was for many years the resort of the leading geologists and men of science in the University, who never failed to find in Mr. and Mrs. Carter genial, cultivated, and hospitable hosts.

Mr. Carter was especially interested in palæontology, and devoted much of his time to this and other scientific subjects. He contributed papers to the Geological Magazine and the Quarterly Journal of the Geological Society, the chief being 'On a New Species of *Ichthyosaurus* from the Chalk,'[1] 'On *Orithopsis Bonneyi*,'[2] 'On a Skull of *Bos primigenius* perforated by a Stone Celt,'[3] 'On the

[1] Brit. Assoc. Reports, 1845 (1846), Sec. p. 60, and Lond. Geol. Journ. 1846, vol. i. p. 8, woodcut.

[2] Geol. Mag. 1872, pl. xiii. f. 1, p. 529.

[3] Geol. Mag. 1874, p. 492.

Decapod Crustaceans of the Oxford Clay,' [1] and 'On Fossil Isopods, with a Description of a New Species.' [2]

Mr. Carter was recognized as an authority on the fossil Podophthalmatous Crustacea, and had for some time been engaged in collecting materials for a monograph on that group; he has left his manuscript in an advanced state. He retained his interest in his pursuits almost till the last, and was engaged in his scientific work to within a few weeks of his death. He was elected a Fellow of the Geological Society in 1877. He served on the Councils of the Geological and Palæontographical Societies for some years, and was a local secretary of the latter society.

Mr. Carter presented his collection of Cambridge fossils to the Woodwardian Museum some years before his death.

Sven Lovén, the eminent Swedish biologist, died at Stockholm, September 3rd, 1895. He was born in the same city on January 6th, 1809; his father was a wealthy merchant, who provided his son with an excellent education, the higher stages of which were carried on partly in the University of Upsala, and subsequently in that of Lund, where Lovén, in 1829, took the degree of Doctor of Philosophy. In the following year he studied zoology at Berlin under such teachers as Ehrenberg and Rudolphi, and then returned to Lund as Docent in Zoology. Several succeeding years were almost exclusively spent in studying the marine fauna, and more particularly the mollusca, of the western coasts of Sweden, and the field of his investigations was afterwards extended to the shores of the northern part of Norway and Finmark.

In 1837 Lovén sailed to Spitzbergen and inaugurated the first of the Swedish scientific expeditions to that island. Though his observations were mainly directed to the marine fauna of this region, the geological phenomena did not escape his observation, and he was the first to discover the Carboniferous strata of the island. He also obtained fossils from newer rocks, which proved to be in part identical with those from the Jurassic beds of Petchora Land, described by Keyserling, and thus established the existence of Jurassic deposits in Spitzbergen.

In 1839 Lovén supplemented his study of the molluscan fauna of the Arctic regions by visits to the Museums of London, Paris, and the principal towns of Germany. He thus fitted himself for the position of Intendant or Keeper of the Lower Invertebrata in

[1] Quart. Journ. Geol. Soc. vol. xlii. (1886) p. 542, pl. xvi.

[2] Geol. Mag. 1889, p. 193, pl. vi. figs. 1-7.

the Swedish State Museum, with the associated title of Professor to the Academy of Sciences, to which he was appointed in 1841. He fulfilled the duties of this office for the long period of 51 years, retiring in 1892, when the natural infirmities of age disabled him from further service. One of the duties assigned to the Intendants of the Museum was the preparation of an annual report, including a record of the general progress in the particular branch of science to which each belonged; in doing this Lovén brought out a fairly complete report of the zoological and palæontological literature of the Lower Invertebrata for the years 1840–49, in three thick volumes. The great increase of scientific literature after this latter date would have needed all the time of the Intendant to keep a proper record of it, and therefore the obligation was abolished.

Lovén's repeated journeys across Sweden by way of the Göta canal, from Stockholm to Bohuslän on the west coast, gave him an opportunity of studying the geology of the country, and so intimately was he acquainted with it that (on Berzelius's recommendation) he accompanied Sir Roderick Murchison from Göteborg to Stockholm, bringing under his notice the best known Silurian localities in Eastern and Western Gotland. The friendship then formed was pleasantly renewed some ten years later, when he met Murchison and the late Prof. John Morris at Marienbad.

The critical knowledge possessed by Lovén of the Mollusca of the Arctic and North Seas enabled him to recognize the distinctly Arctic character of the shells in the Glacial deposits of Sweden, now elevated considerably above the sea-level. He first pointed out, in 1839, this evidence of the former presence of an ice-cold sea over parts of Sweden. Later on, in 1860, he published several papers on certain Crustacea and fishes, now living in the larger inland lakes of Sweden, which were shown to be the descendants of forms inhabiting Arctic seas, constituting a relict-fauna which had thus survived the changes of habitat and climate.

Lovén's researches on the Mollusca continued up to 1860; from then onwards to the close of his career, a period of over 30 years, his energies were devoted to the study of Echinodermata. His renown as a biologist will mainly rest on his magnificent work on the Echinoidea, as shown in the two principal memoirs 'Études sur les Échinoïdes,' published in 1874, and 'On *Pourtalesia*, a genus of Echinoidea,' in 1883. Among the authors who have most clearly illustrated the developmental history and the organic relations of the Echinoidea, Sven Lovén will stand in the foremost rank.

From his early days Lovén recognized the intimate reciprocal

connexion of zoology and palæontology; this standpoint was steadily followed in his great work on the Echinoids, and he gave a practical expression of his views on this subject by arranging the fossil and recent representatives of this group side by side on the same shelves in the State Museum at Stockholm.

Both in his own country and abroad, Lovén was honoured as a master in natural-history research, and his amiable character and personal kindness endeared him to his colleagues and fellow-Academicians in Stockholm. He was chosen a Corresponding Member of the Institute of France in 1872, a Foreign Correspondent of the Geological Society in 1863, and a Foreign Member in 1882. He was further a Foreign Member of the Royal Society, and of the Academies of Berlin and Vienna. And lastly, in 1893, he received the Prussian Order 'Pour le Mérite.'[1] (G. J. H.)

The Hon. WALTER BALDOCK DURRANT MANTELL was the eldest son of Dr. Gideon Mantell, F.R.S., F.G.S., the well-known Sussex geologist and discoverer of the *Iguanodon*. He was born in 1820, and left England about 1840 for New Zealand, where he became a man of great public importance, holding the posts of Minister for Native Affairs, Postmaster-General, and Secretary for Crown Lands. He was ever mindful of the interests of the Maoris, and sought to serve them to the utmost of his power.

In 1847 Mr. Mantell sent home the first remains of *Notornis*. These were described by Owen as belonging to an extinct form, but two years later, in 1849, Mantell obtained from some sealers on the south coast of Middle Island (now called the South Island), where he was Government Commissioner for the Settlement of Native Claims), a skin together with the skull and some limb-bones of a *Notornis* recently hunted down with dogs, and killed and eaten by these men. Not long afterwards another smaller skin was obtained. Both these specimens are preserved in the Natural History Museum.

The bird was apparently unknown to the Maoris, but there are traditions of a 'Swamp-Hen,' called on the North Island 'Moho,' and in the South 'Takahé,' which may have been the *Notornis*.

In 1868 Mantell read a paper before the New Zealand Institute[2]

[1] For many of the data in the above notice the writer is indebted to the sympathetic notice of his late colleague by Prof. G. Lindström in Geol. Fören. i Stockholm Förhandl. Bd. 17, Häft 6, 1895, pp. 627–638.

[2] Trans. New Zealand Institute, vol. i. 1868.

'On the Moa,' in which he insisted that these birds were contemporaries of Man, their remains being found charred and broken in the Maori ovens, together with stone implements. He also discussed the cause of the extinction of the Moa, and ascribed it chiefly to the agency of man, a view now generally accepted.

In a later paper read before the Wellington Philosophical Society, 1872, he discussed statements that had been made, that Moa-bones had been found beneath marine deposits with extinct shells, and stated that this idea arose from a misapprehension of some information supplied by him to his father, who employed it in his paper before the Geological Society.[1] He also gave an account of some new localities in which Moa-remains had been found, including Waikonaiti and Te-Rangatapu. In the latter he obtained a large number of fragments of Moa-eggs, several of which he succeeded in restoring. Some of these specimens are now in the Natural History Museum.[2]

Mr. Mantell was elected a Fellow of the Geological Society in 1858. He died on September 7th, 1895, at the age of 75 years. He was in correspondence with Sir William Flower, at the time of his death, as to a further donation of his remaining private collection of Moa-remains to the British Museum, which it is hoped may still be made by his representatives at Wellington, New Zealand.

Richard Carter, elected a Fellow in 1874, died on September 26th, 1895, aged 78, at Springbank, Harrogate, Yorkshire.

John Ellor Taylor, Ph.D., F.L.S.—As an enthusiastic lover of Nature, and a popular exponent of geological and botanical science, Dr. Taylor did much to arouse in others an interest in natural-history subjects. The son of the foreman of a cotton factory, he was born at Levenshulme, Manchester, September 21st, 1835, and was employed in early years in the railway-works at Crewe. Developing a taste for literature and science, he read largely, cultivated a facile style of writing, and became a contributor to a Manchester paper. His leisure hours were devoted to geology,

[1] See Quart. Journ. Geol. Soc. vol. iv. (1848) pp. 225-241. [The woodcut which gave rise to the misapprehension is probably that on p. 240.]

[2] See 'Notice of the Remains of *Dinornis* and other Birds, and of Fossils and Rock-specimens, recently collected by Mr. Walter Mantell in the Middle Island of New Zealand. By G. A. Mantell. With Notes by E. Forbes, and Sketch-map and Notes by Walter Mantell.' Quart. Journ. Geol. Soc vol. vi. (1850) p. 319.

and in his first work, 'Geological Essays' (1864), he gave a sketch of the geology of Manchester and its neighbourhood. About the year 1862 he settled in Norwich, as sub-editor of the 'Norwich Mercury,' and stirred up much interest in the geology of the country round the old city. He drew attention to the disturbed Chalk at Whitlingham, Swainsthorpe, and other places; he pointed out the differences in the Mollusca preserved in the two shell-beds in the Norwich Crag at Bramerton; and, in conjunction with the late John Gunn, he established the Norwich Geological Society, which is now incorporated with the Norfolk Naturalists' Society. Before these local societies, and the British Association, the results of his geological observations were chiefly brought: and records of his work are printed in the earlier volumes of the Geological Magazine. In 1866 he published a little introduction to geology, entitled 'Lithographs,' and subsequently other popular works on natural history flowed from his pen. In 1872 he was appointed Curator to the Ipswich Museum, a post from which he retired through ill-health about two years ago. He contributed a capital 'Sketch of the Geology of Suffolk' to White's History of the county. For many years he was editor of 'Science Gossip'; while his science lectures at Ipswich and elsewhere were widely appreciated. Of late years he was a strong advocate of the search for coal in East Anglia. Dr. J. E. Taylor was present in the Geological Section of the British Association at Ipswich in September last, and spoke on the subject of the deep boring in search of coal at Stutton. He then definitely stated his opinion that, although unfavourable to the anticipations and hopes of himself and others, the boring had brought up a sample of the Yoredale Shales below the real Coal-measures. He died at Ipswich on September 28th, 1895.

The Rev. EDWARD DUKE, M.A., J.P., was elected a Fellow of the Geological Society in 1856. He was author of a book entitled 'Beneath the Surface, or Physical Truths, especially Geological.' He died at Lake House, near Salisbury, on Oct. 17th, 1895.

In Señor Don ANTONIO DEL CASTILLO, Director of the National School of Engineers, and of the Geological Survey of Mexico, America has lost a most able geologist, and the Geological Society a distinguished Foreign Correspondent. He was the author of a descriptive 'Catalogue of the Iron and Stone Meteorites of Mexico' (8vo, Paris, 1885), 'The Fossil Fauna of the Sierra de Catorce, San

Luis Potosi' (see Geol. Mag. 1895, p. 522), the 'Antropologia Mexicana,' 'El Hombre del Peñon' (Mexico, 1885, 8vo), also of numerous other memoirs and a large number of excellent geological maps. He died in Mexico city on October 22nd, 1895. He was in England at the Meeting of the International Geological Congress in 1888, and Commissioner for Mexico at the International Mining and Metallurgical Exhibition at the Crystal Palace, Sydenham. He was elected a Foreign Correspondent in 1891.

Philip Henry Lawrence was born in Liverpool in 1822, and was admitted as a solicitor in 1848. He took an active part in forming the Commons Preservation Society, and acted as its solicitor until he ceased to practise in that branch of the profession. In 1872 Mr. Lawrence was called to the Bar at Lincoln's Inn. He had been elected a Fellow of the Geological Society in 1866.

He was the translator of Bernard von Cotta's 'Lithology,' a well-known handbook on rocks. Mr. Lawrence died at 8 Royal Crescent, Brighton, on October 17th, 1895.

Captain Charles Tyler, F.L.S., was born in London in August 1826, and was educated at University College.

He was a man of scientific tastes, an ardent microscopist, and a member of many learned societies. He joined the Microscopical Society in 1858, was elected a Fellow of the Linnean Society in 1862, and of the Geological Society in 1863. He served for many years on the Councils of the Palæontographical and the Ray Societies, and was for some time a member of the Honourable Corps of Gentlemen-at-Arms.

Capt. Tyler gave valuable assistance to Dr. Bowerbank in the examination of exotic sponges, when he was preparing his Monograph on the British Spongidæ for publication. He formed a large collection of fossils, and possessed many microscopes and a valuable collection of slides.

One of the chief interests of his life was his connexion with the Orphan Working School, Haverstock Hill, to which he devoted himself with characteristic energy and close personal attention during nearly forty years. During his later years he gave much attention to the administration of St. Thomas's Hospital, where he served repeated terms of office as Almoner.

Capt. Charles Tyler, who was in the 70th year of his age, died on November 2nd, 1895, after a short illness, which, however, was the climax of a long period of failing health.

E. A. WÜNSCH was one of the original members of the Glasgow Geological Society, which was founded in 1858, and served the office of Vice-President several times from 1858 to 1881, when he left Glasgow to reside at Carharrack, Scorrier, Cornwall. There he died on November 19th, 1895, aged 73 years. He was elected a Fellow of the Geological Society in 1875.

The most important service which he rendered to geological science was his discovery in 1865 of erect trees buried in volcanic ash in Arran. These trees were discovered in the Lower Carboniferous strata of the north-eastern part of Arran, in the sea-cliff, about 5 miles north of Corrie, near the village of Laggan. Here strata of volcanic ash occur, forming a solid rock cemented by carbonate of lime and enveloping trunks of trees, determined by Mr. Binney to belong to the genera *Sigillaria* and *Lepidodendron*. Sir Charles Lyell mentions that he visited the spot in company with Mr. Wünsch in 1870, and saw that the trees with their roots, of which about fourteen had been observed, occur at two distinct levels in volcanic tuffs, parallel to each other, and inclined at an angle of about 40°, having between them beds of shale and coaly matter 7 feet thick. It is evident that the trees were overwhelmed by a shower of ashes from some neighbouring volcanic vent, just as Pompeii was buried by matter ejected from Vesuvius.[1]

Mr. Wünsch writes[2]:—'Trunks of trees 18 to 24 inches in diameter, and 2 to 3 feet in height, standing erect upon the original beds of thin coal and shale upon which they grew, and covered by layers of ash 2 to 3 feet in thickness, are found regularly dispersed over the area: while the ash overlying them, in which they are embedded, contains numerous branches, from 4 inches in diameter down to the minutest dimensions, some of the impressions displaying an almost feathery foliage, as though suddenly covered up before the vegetation had had time to decay, or become waterworn. The larger branches remain perfectly round, and show the pith in an admirable state of preservation; and the cellular tissue, filled up with mineral matter, is plainly visible to the naked eye.'

His last paper was 'On a Logan-stone in the course of formation at St. Michael's Mount,' Trans. Roy. Geol. Soc. Cornw. 1895, pp. 605 & 669.

[1] Lyell's 'Student's Elements,' 4th ed. 1885, pp. 496–497.

[2] Geol. Mag. 1865, pp. 474–475; *ibid.* 1867, pp. 551–552.

Prof. Dr. LUDWIG RÜTIMEYER, Foreign Member of the Geological Society of London, was born at Biglen in the Commenthal, Canton Bern, in 1825. His father was a parish clergyman and afterwards Superintendent of the Orphanage at Bonn. Ludwig was educated in the High School and Gymnasium of that town, and in 1842 went to the University of Bern, where he studied theology, with the intention of following his father's profession. Having developed a taste for comparative anatomy, no doubt partly through the influence of his friend Peter Merian, the Basel palæontologist, he forsook his theological studies, and took up medicine. Afterwards he visited many of the chief European cities, and in Paris in 1850 he became acquainted with Élie de Beaumont. In 1852 he came to London, which he again visited in 1877. In 1854 he took up academical teaching in the Bern University, but in the following year he accepted the newly-established Chair of Zoology and Comparative Anatomy at Basel, which he held till his death.

On the occasion of his second visit to London he spent some weeks in a critical examination of the fossil *Bovidæ* from the Older Pliocene of the Siwalik Hills, India, part of the Falconer and Cautley Collection, preserved in the British Museum.

His first work, 'Vom Meere bis nach den Alpen,' was published on his return from his travels in 1854; after this he issued a long series of memoirs, characterized by the great accuracy and detail of their observations, and the wide philosophical grasp and far-reaching deductions made from them.

Some of the more important of these memoirs are:—'Untersuchungen der Thierreste aus den Pfahlbauten in der Schweiz,' 1860, in which he gives an account of the earlier races of some of the domestic animals, and shows that while in the Lake-dwellings of the Stone Age the remains of wild animals predominate (proving that the inhabitants lived mainly by the chase), in the later settlements, made after the use of metals was discovered, the inhabitants relied chiefly on various domesticated animals for food.

Another important paper is 'Beiträge zur Kentniss der fossilen Pferde und zu einer vergleichenden Odontographie der Hufthiere im Allgemeinen,' 1863; this may be regarded as laying the foundation of that detailed comparative morphology of the teeth, in which the homologies of the several cusps are considered, and from which the American palæontologists have been able to draw very

important conclusions as to the phylogeny of many groups of mammals.

In a paper entitled 'Ueber die Herkunft unserer Thierwelt: eine zoogeographische Skizze,' 1867, Rütimeyer gives a masterly account of the distribution of the mammalia, showing the relations of the fossil faunas to one another and to recent forms. It is a testimony to his sagacity that the great additions to our knowledge of this subject have confirmed most of his conclusions, and have rendered very few untenable.

He was elected a Foreign Correspondent of the Geological Society of London in 1877, and a Foreign Member in 1882.

Up to the time of his death Prof. Rütimeyer maintained a lively interest in all scientific researches, and carried on his correspondence to the last. He died at Basel on November 26th, 1895.

The Ven. Archdeacon ROBERT W. BROWNE, M.A., Prebendary of St. Paul's, was elected a Fellow of the Society in 1833, and died at Wells on December 12th, 1895, in his 87th year.

The Rev. LESTER LESTER, who was elected a Fellow of the Geological Society in 1856, died on December 26th, 1895, at his residence, Langton Maltravers Rectory, Wareham, Dorset.

HUGH MILLER, F.R.S.E., was born on July 15th, 1850. He received his scientific education at the Royal School of Mines, being nominated thereto by Sir Roderick Murchison. Bearing the same name as his distinguished father, the author of 'The Testimony of the Rocks,' 'The Old Red Sandstone,' etc., Mr. Hugh Miller inherited with the name a taste for geological pursuits. He joined the Geological Survey in 1874, and was elected a Fellow of the Geological Society in the same year. Labouring at first among the Carboniferous Rocks and Glacial Drifts of Northumberland, he was subsequently transferred to the Geological Survey of Scotland, and worked at the Old Red Sandstone around Cromarty, rendered classic by the researches of his father. Later on he mapped portions of the Ancient Schists, Old Red Sandstone, and Drifts of Eastern Sutherland. Mr. Hugh Miller was taken ill at Lairg in December last, and died at his Edinburgh residence on January 8th, 1896, in his 46th year.

He was author of the picturesquely-written book entitled 'Landscape Geology,' and of papers on River Action and Glacial Phenomena. Among the more important of these papers the following

may be mentioned:—'Tynedale Escarpments: their pre-Glacial, Glacial, and post-Glacial Features,' 1880; 'River-Terracing: its Methods and their Results,' 1884; and 'On Boulder-Glaciation,' 1884.

All who enjoyed Mr. Miller's friendship will feel that they have lost a kind-hearted, though keenly sensitive, friend. Strongly imbued with a love of Nature and natural phenomena, he at the same time kept himself in touch with the intellectual life of our time. He leaves a widow and a son, fifteen years of age, who is being educated at Fettes College.

Joseph Walter Tayler was elected a Fellow of the Geological Society in 1856. He was the son of the late Admiral Tayler, R.N., and made several expeditions to Greenland with the object of exploring the east coast and opening up again the old Danish settlements said to have formerly existed along its shores, but now completely blocked by the ice-pack. He was the discoverer of cryolite at Evigtok, Greenland (see Quart. Journ. Geol. Soc. vol. xv. 1859, p. 140), and gave an account of veins of tin-ore at Evigtok (*op. cit.* p. 606). He was an enthusiastic Arctic explorer, and gave to the Royal Geographical Society some interesting observations on the Greenland glaciers, which he had carefully studied.

Frank Johnston, F.C.S., was by profession an Assayer at the Rio Tinto Company's Mines. He was elected a Fellow of this Society in 1884, and died at Tharsis, Huelva, Spain, in January 1895.

John Evelyn Williams, M.Inst.C.E., was born on January 6th, 1845, and entered the drawing office of the Mersey Dock Estate, Liverpool, at the age of 14; there he remained for six years. He was afterwards engaged on dock- and harbour-works at Bristol, Hull, and Whitehaven. In 1877 he became Surveyor to the Witham Drainage Commissioners, and was actively engaged in the improvement of the drainage and harbours of one of the most important tracts of the Fenland until about a year before his death, having retired from that service in 1895. Mr. Williams was elected a Fellow of the Geological Society of London in 1880. Several important memoirs upon the work carried out by him have appeared in the Minutes of Proceedings of the Institute of Civil Engineers.

W. Stert Milnes was elected a Fellow in 1886. He died at Yeolmbridge, Launceston, Cornwall, in 1895.

G. W. Cline, LL.D., was elected a Fellow in 1865. He resided at Allahabad, India, where he died.

Edward John Chance, F.L.S., was elected a Fellow in 1837. He died at 14 Russell Square, W.C., in 1895.

Mr. Francis Everard Brown, Assistant-Clerk to the Geological Society, died suddenly from gastric ulcer on August 4th, 1895.

The Society loses in him an official whose unvarying patience, tact, and good-humour had made him deservedly popular among the Fellows, and whose scrupulous performance of his duties had earned him the respect and esteem of his official superiors.

He entered the Society's office in 1886, and had nearly completed ten years' service when his career of usefulness was brought to a close.

Always delicate in health even when a child, he was unable to indulge in those athletic sports with his schoolfellows which form the delight of most boys; and he was thus led early in life to take up the study of Natural History, and to make observations on animals and flowers. This developed in him later on a taste for scientific reading.

He collected autographs, took great interest in all matters connected with the fine arts, and had commenced to study and collect minerals and fossils.

Mr. Brown entered Messrs. Fulcher and Robinson's office when only 15 years of age, and afterwards was with Mr. Sims, a stockbroker, before he obtained his appointment at Burlington House. Here he speedily won the confidence of the Treasurer and Secretaries by his willingness and constant readiness and attention; whilst his uniform politeness to the Fellows and visitors speedily engendered a very kind and friendly feeling towards himself, which he retained to the end. He died at the age of 37 years.

By the law of periodicity, which, happily, has a constant biennial limit, in this Society, I am about to vacate the Presidential Chair, in which you did me the honour to place me in 1894: but before doing so, and whilst I may yet claim the privilege of a few remaining sand-grains in Time's hour-glass, let me briefly draw attention to a few topics of general interest connected with our science, and in conclusion submit my second chapter on Crustacean life-history in later geological times for your acceptance.

As regards Home affairs we have just cause for satisfaction with our present financial position as a Society. Our income has not diminished, and we have a very respectable balance in hand, more than sufficient for our ordinary expenditure, and probably nearly sufficient to meet such extraordinary expenses as the installation of the electric light and the partial re-decoration of the Society's House.

It is satisfactory to find that the slight increase in our composition-fee for admission to the Society (decided upon in June 1894) has not acted as a deterrent to intending compounders, but that we have actually had more compounders during this last year than previously.

The completion of the 50 years' index has been somewhat retarded by the death of our valued and esteemed Assistant-Clerk, Mr. Francis E. Brown, which placed, for the time being, a heavy load of additional business responsibility on our Assistant-Secretary, who was happily equal to the emergency, and the Society suffered no serious inconvenience from the temporary vacancy in the staff.

The first number of 'Geological Literature added to the Geological Society's Library,' during the half-year ended December 1894 (8vo, pp. 58), was issued on the 1st May, 1895. On February 1st, 1896, a similar work was issued, covering the year 1895. It extends to 158 pp. (8vo), and will certainly prove extremely valuable to all workers in our science, particularly to Fellows in the country, desirous of knowing what our library contains of the latest geological interest.

The fifty-first volume of the Society's Journal, for 1895, compares favourably in every way with its predecessor.

Mr. E. T. Newton, F.R.S., announces the discovery of human remains from Palæolithic gravels at Galley Hill, Kent—which, if (in point of contemporaneous age) still involved in doubt, are yet of extreme interest to the student of Quaternary geology. Dr. G. J. Hinde and Mr. Howard Fox give a most interesting account of

the discovery of Radiolaria in the chert of the Culm-beds of Devon, Cornwall, and West Somerset; and Messrs. W. Hill and A. J. Jukes-Browne describe the occurrence of Radiolaria in the Chalk.

Mr. S. S. Buckman, in his paper on the Bajocian of the Mid-Cotswolds, records the results of a vast amount of detailed stratigraphical and palæontological work based upon the Ammonite and Brachiopod faunas of this area. Dr. J. W. Gregory treats of the Palæontology and Physical Geology of the West Indies. There are three papers on Madagascar: (1) by the Rev. R. Baron on the Geology of the Northern part of that island; (2) by Mr. R. Bullen Newton on the Fossil Mollusca; and (3) by Mr. R. Lydekker on a Sauropodous Dinosaur from the same region.

Prof. Amalizky contributes a paper on the Permian Freshwater Lamellibranchiata from Russia and South Africa; Mr. H. M. Bernard one on the Systematic Position of the Trilobites; and Miss J. Donald treats of British Carboniferous Species of *Murchisonia*.

I refer to these papers in order to express the hope that they may be taken to indicate (like the periodic variations in climatic conditions) a recent tendency in students of geology to turn towards palæontology, and not to entirely ignore her in favour of her sister petrology.

Thirty-four other papers deal with dynamical, petrological, physiographical, and stratigraphical geology, in all quarters of the globe, and demonstrate the earnest and active interest which the Fellows of the Society take in the promotion of our science.

The Geological Survey of the United Kingdom.

In the early days of the Geological Survey my predecessors made a point of commenting on the annual progress made by that Institution, and remembering that some of the early fathers of the Society had a share in the establishment of the Survey, we may naturally feel a parental interest in its welfare.

Some years have now elapsed since any special Presidential remarks were made on the subject; a brief reference by Prof. Judd, a former member of the staff, appears in his address to this Society in 1887, but the latest general account of progress was given so long ago as 1868, by Sir Warington Smyth, who, likewise an old member of the Survey, had in former years mapped some areas, and had in particular traced the course of many metalliferous veins in his capacity of Mining Geologist.

To note the special scientific results obtained by the Geological Survey has, however, during the past few years, been rendered unnecessary by the publication of the more detailed Reports of the Director General. It is the more desirable to draw attention to this fact, for the reports themselves, unless obtained in the form of reprints, are apt to lie buried in the more bulky General Report of the Science and Art Department. That Report must now be added to our record of Geological Literature, for in the elaborate statement of Sir Archibald Geikie we find many a new and interesting fact for the first time recorded, whether it relate to England or Wales, the Isle of Man, Scotland, or Ireland.

In parts of all these regions the Survey is actively engaged. The mapping of the Drift deposits in the Midland and Southern counties has been accompanied by important revisions of the more solid geology, and the results of the work are to be seen in the issue of sheets of the New Series of Ordnance Maps, geologically coloured, of parts of Sussex, the Isle of Wight, Hampshire, and Devon. The re-survey of the great coalfield of South Wales has already borne fruit in the shape of one new map and a sheet of vertical sections.

The progress of the 4-mile-to-1-inch map of England and Wales is of especial interest to us, as eventually it will replace our Greenough map, which was based on the original map of William Smith. Of the Survey map, which comprises thirteen sheets, seven are now published, five, we are informed, are being engraved, and one (the Isle of Man) will erelong be completed. A most important change has this year been introduced by the Director-General, that is, the issue of one of the sheets (that of the London Basin and great part of the Wealden area) printed in colours. Thereby the price has been reduced from 10*s*. 6*d*., that of the hand-coloured issue, to 2*s*. 6*d*.—a boon indeed to the geologist, and a course well calculated to ensure the wide circulation of the map.

Another departure made by the Director-General has been the preparation of Stratigraphical Memoirs, and of these one volume on the Pliocene Deposits, and five on the Jurassic Rocks have now been issued. In them our present knowledge from all sources is summarized, so that they may furnish stepping-stones to further progress.

In Scotland interest of late years has been centred in the resolute attacks made by the Survey on the problems connected with the Scottish Highlands. Following in the wake of Murchison, Nicol, and Lapworth, the officers in the field, headed by their

Director-General, have grappled with the difficulties and by dint of detailed work on the 6-inch scale have brought order into the structure of these complicated regions. Moreover they have demonstrated that in many respects the interpretation of Nicol, and the key furnished by the hard work of Lapworth, have been most successful in unlocking the secret of the Highlands. The maps which picture the results of the Survey work are probably the most elaborate that have ever been issued.

Elsewhere the Survey has been carried on among certain of the Western Islands in Skye, Raasay, and Rona, in Canna and Islay, and farther south in Arran.

In Ireland important revisions have been made in the older work, especially among the Palæozoic, the Metamorphic, and the Igneous rocks. The results may be studied in that excellent guide to the Survey Collections in the Dublin Museum which has lately been issued.

In noticing thus briefly the work of the Survey, I cannot avoid remarking on the notable accession made to the staff during the past eight years, of Teall, Lamplugh, Watts, Sollas, Gibson, and lastly of Harker.

Among these additions it will be noticed that a very strong Petrological element has been introduced into the Geological Survey—needful, however, in solving the problems connected with the ancient schists and other metamorphic rocks, and in elucidating the structure of our various igneous rock-areas.

Nor has Palæontology been neglected, in testimony of which we need only mention the papers by Mr. Peach in our own Quarterly Journal on the *Olenellus*-fauna of Scotland, and the new and strange forms of Reptilia lately described by Mr. E. T. Newton from the Elgin Sandstone—forms which are of world-wide interest.

The acquisition of scientific facts is, however, by no means the sole or main object of the Geological Survey. In the re-survey of our coal-fields the practical element is foremost, while in the London office all information that can be given is freely at the service of those interested in the industrial applications of geology.

By the death of Huxley the Palæontographical Society loses its President, an office which he had held since the death of Prof. Owen, its former President, in 1892.

But no change of Presidents can mar the useful and perennial flow of volumes issued by this evergreen Society, which has just

reached its Jubilee, and, like all successful and united people, it ought to celebrate the publication of its 50th volume in some suitable manner.

The 49 volumes already published are the joint labours of 46 authors, about 12 of whom have, however, achieved the greater share of the work produced. Prominent among these stand such names as Searles V. Wood, Richard Owen, Thomas Davidson, Edwards and Haime, F. E. Edwards, T. Rupert Jones, T. Wright, P. M. Duncan, H. A. Nicholson, G. J. Hinde, G. F. Whidborne, Salter, and others.

Very much of the success which has attended the Society must be attributed to the constant care and untiring energy of its Honorary Secretary, the Rev. Prof. T. Wiltshire, who has continually watched over the work and managed all the business details of the Society since he took over the duties from the first Secretary, Dr. Bowerbank, thirty years ago.

I feel that I should be wanting in gratitude to my many geological friends and supporters, did I omit, on this occasion, to thank them most heartily for the aid that they have always afforded me in carrying on the Geological Magazine for the past 32 years.

It is no easy task to arrange and get printed off 48 pages of matter on one special branch of science, and issue it regularly, with illustrations, for 380 consecutive months—but like other literary enterprises and institutions, 'supported by voluntary contributions,' we might well inscribe on the cover of the Magazine as our motto *Dominus providebit*; for, certainly, we have been singularly fortunate in our friends and supporters, amongst whom, in the past, as in this latter-day revival, we ought especially to remember the names of Prof. T. G. Bonney, Mr. W. H. Hudleston, and Dr. G. J. Hinde.

Through the death of Prof. Huxley, the Royal College of Science was deprived of its Dean and a Professor who had been connected with its teaching body for 41 years.

The office of Dean has since been conferred upon Prof. John W. Judd, C.B., LL.D., F.R.S., who succeeded Prof. Sir A. C. Ramsay in the chair of Geology in the then 'Royal School of Mines' in 1877, which was transfigured into the 'Royal College of Science' in 1881. Prof. Judd is a past President and Secretary of this Society, and we trust that he may long retain his deanery, to the advancement of the various sciences committed to his charge.

Sir Joseph Prestwich, D.C.L. (Oxon.), F.R.S., now in his 84th year, received the honour of knighthood from Her Majesty on New Year's Day. While we all heartily rejoice with and congratulate him and Lady Prestwich on the honour conferred, we cannot help feeling that the eminence to which he had long ago attained by his scientific labours far transcends such tardy recognition of his great and lasting services to geological science.

A rumour had reached me that our distinguished Foreign Member, Prof. James Hall, of Albany, who was elected on our Foreign list in 1848, and was Wollaston Medallist in 1858, had retired from his office of State Geologist of New York. I find this is not the case, the only change being that he has relinquished the post of Director of the Albany Museum since 1893, but he still holds the office of State Geologist. Thirteen imperial quarto volumes on 'the Palæontology of the State of New York' have been issued by Prof. James Hall, and, at the age of eighty-five years, he is still full of life and intellectual activity and engaged on a monograph on Fossil Sponges, the MS. of which is now nearly completed, with 30 quarto plates already drawn and lithographed.

We cannot but express our admiration for the marvellous energy and determination to carry on his work to the end, displayed by the illustrious Professor. In this country science has a more enervating and exhausting effect on Civil Servants, and they are deemed past work at sixty-five! Wherefore we are disposed to envy the happy lot of our old and valued friend.

Sir J. William Dawson, C.M.G., F.R.S., whose name will be always identified in this Society with his discoveries of air-breathing reptiles, land-snails, and myriopods, in erect, but hollow, trunks of trees, of Carboniferous age in the South Joggins Coal-field (Nova Scotia), and with his papers on *Eozoon* and 'Acadian Geology,' etc., held the office of Principal of M'Gill College, Montreal, since 1855, but has now retired into private life after a long and brilliant career. Sir William is still in full activity, and purposes to be at the Liverpool Meeting of the British Association this year. He received the award of the Lyell Medal in 1881. Sir William Dawson's Chair of Geology and Palæontology has been given to Prof. Frank Dawson Adams, M.A.Sc., Ph.D., F.G.S., a very able and promising geologist.

Another change has occurred in Canada by the retirement from office of our esteemed Fellow, Dr. Alfred R. C. Selwyn, C.M.G.,

F.R.S., from the post of Director of the Geological Survey of Canada; he had succeeded Sir W. Logan in 1869. He joined the English Survey in 1845, went out as Director of the Geological Survey of Victoria, Australia, in 1853, and was there through all the excitement of the opening up of the gold-fields of that colony. In 1869, he transferred his services to Canada, where he held office until 1894. Counting home and colonial service, Dr. Selwyn has been 49 years on active duty, and has served as Commissioner to three International Exhibitions. He received the Murchison Medal in 1876.

Dr. Selwyn has been succeeded as Director by Dr. George M. Dawson, C.M.G., F.R.S., F.G.S., eldest son of Sir William Dawson, who was on the North American Boundary Commission in 1873, and joined the Geological Survey in 1875. He has already served on several Royal Commissions, the last being that on the Behring Sea Fisheries; has made numerous communications to this Society, and was the recipient of the Bigsby Medal in 1891.

Dr. G. M. Dawson is one of the few individuals (of whom Sir Charles Lyell in 1864 was another instance) who may have read his own obituary, for his death was announced on November 12th, 1895, but was speedily contradicted by Sir Charles Tupper, High Commissioner for Canada, who cabled out at once and found that an error in the spelling of the name had changed *L*awson into *D*awson.

In our Indian Empire Dr. William King, B.A., who joined the Geological Survey in March 1857, and succeeded Mr. Medlicott as Director in 1887, retired from office on July 16th, 1894. During the 37 years of Dr. King's connexion with the Survey he published thirty-five papers, dealing mostly with the geology of the southern and central parts of India. He was succeeded on July 17th, 1894, by Mr. Carl L. Griesbach, C.I.E., F.G.S., who joined the Survey in Sept. 1878. Mr. Griesbach is the author of 26 papers on geology, from 1868 to 1893. He was employed on the Afghan Boundary Commission, from November 1884 to October 1886, and as Geologist to His Highness the Amir of Kabul, from January 1888 till July 1889. He has contributed some important work on the geology of the Himalayas, and received the gold medal from the Emperor of Austria in recognition of his services rendered in connexion with the scientific expedition in 1892 to the central regions of the Himalayas.

Another of our Fellows, Prof. John Milne, F.R.S., after spending

20 years at the Imperial College of Engineering, Tokio, Japan, and devoting his time and income to the investigation of earthquake-phenomena in that centre of remarkable disturbance, has now returned home from Japan and has established a station for seismological observations in the Isle of Wight.

Some of his latest researches on the propagation of earthquakes to great distances have led him to most interesting conclusions.

In the case of the Argentine earthquake of 1894 Milne was successful in showing that a large disturbance might be recorded at the antipodes of its origin. The pronounced movements of an earthquake travel over paths around an epicentre at a rate of 2 or 3 kilometres per second, and they are transmitted, at the same rate, to places distant more than a quarter of the earth's circumference. Preceding these pronounced movements which apparently radiate as quasi-elastic gravitational waves, minute tremors are observable, which, in travelling from Japan to Europe, apparently outrun the main disturbance by half-an-hour. The velocities at which these are propagated have been estimated as varying between 8 and 20 kilometres per second.

Assuming these determinations to be approximately correct, it is difficult to escape the conclusion that the motion, instead of having been transmitted through the crust of the earth, has been transmitted through its interior. Prof. Milne writes:—'When a number of properly-equipped observing-stations have been established around our globe, it seems likely that we shall be in a position to state definitely the velocity with which motion travels along paths at varying depths in the earth's interior. From the little already accomplished, it appears that, if our globe is capable of transmitting motion two or three times more quickly than steel, it has an effective rigidity very much higher than has hitherto been supposed.'

Thanks to these researches and experiments, carried out in coöperation with the late E. von Rebeur-Paschwitz and other observers in Europe, we may hope, possibly within a few years, to have a definite solution of what has heretofore been to geologists truly a *terra incognita*—the nature of the structure of the interior of the earth.

On his retirement in 1895, Prof. Milne received from the Emperor the well-merited decoration of the Rising Sun, in recognition of the valuable scientific work performed by him during his long residence in Japan.

Life-history of the Crustacea in Later Palæozoic and in Neozoic Times.

In my Address, in February last year, I endeavoured to set before you as briefly as possible, an epitome of the more interesting points in the earlier chapters of the life-history of the Crustacea—a Class so ancient as to entitle it to take precedence over the whole of the Vertebrata, and probably over half the Invertebrata also, in the geological record.

From Lower Cambrian times to Carboniferous we showed that the Crustacea were mainly represented by the great and numerous order of the Trilobites, while bivalved Ostracods, huge Pod-shrimps (Phyllocarida) and giant Merostomata, such as *Eurypterus* and *Pterygotus*, with a few small King-crabs, fill up the picture of marine crustacean life.

To whatever part of the world we direct our gaze over the Palæozoic seas, the same group of organisms is more or less abundantly represented;—indeed it may be said that, until we reach the Upper Silurian, the Trilobites almost entirely occupy the primæval waters to the exclusion of other crustacean life. But from this stage upwards the Trilobites are more restricted, while the large Pod-shrimps, *Ceratiocaris*, appear in numbers, together with the gigantic *Pterygotus*, the latter attaining its maximum in the Old Red of Scotland.

Some 8 or 9 genera of Trilobites still continue on in the Devonian and the Carboniferous Limestone, in the latter formation reduced to about four genera, after which they disappear entirely.

Whether the Trilobites continued to live on in some of those marine areas which probably existed adjacent to the larger fresh-water and estuarine ones, amidst which the great subaerial growths of the Coal-period were being accumulated, we do not certainly know, but in the succeeding Permian epoch they have left no evidence behind.

As we scan the record of these old Carboniferous rocks, so rich in organic remains, we seem to stand on some lofty beacon-hill, whence we can cast our glance upwards and downwards along the stream of time. Beneath our feet lie buried the last representatives of those aboriginal races now quite extinct, the Trilobita and the Eurypterida, whose ancient hosts peopled the seas of Devonian and Silurian ages and some of whose predecessors reached far away to the Lower Cambrian epoch. Beside them lie the earliest representatives known of our modern Decapoda, Stomatopoda, and Isopoda, then but a few and feeble folk, but now the dominant races of the

Crustacean class. Is this then the great barrier-reef between the Palæozoic and Neozoic life-periods? Do we indeed find here the beginning of all modern forms of Crustacea and the ending of all ancient ones?—By no means; nor is there any period in the whole geological record at which a hard-and-fast line can be drawn dividing the earlier from the later members of any group.

Certain tribes, such as the Entomostraca, are represented throughout. Others, like the Amphipoda, may perhaps extend into Silurian times,—whilst Isopods and Decapods are probably represented as far back as in Devonian strata.

The Crustacea, in fact, bear testimony to the same general biological law which holds good in so many other classes of organisms, namely, that before one order dies out and disappears, other and successive groups have already made their appearance: the one overlapping the other in time.

There are, indeed, no sharp divisions in living Nature, but rather a subtle interblending of groups which, like the prismatic colours in the rainbow, shade off imperceptibly the one into the other.

MALACOSTRACA.—Throughout the sub-class MALACOSTRACA, to which so large a proportion of the Mesozoic, Cainozoic, and Recent forms of Crustacea belong, the number of segments present is generally very persistent for the three divisions of the body (head 6, thorax 8, and abdomen 7 = 21). They fall naturally into two groups, (1) the EDRIOPHTHALMA, in which the eyes are sessile, and (2) the PODOPHTHALMA, in which they are pedunculated.

AMPHIPODA.—In the Amphipoda belonging to the first of these divisions, with sessile eyes, the body is pretty constantly and regularly developed, the small cephalothoracic head-shield only covers its own series of seven paired appendages, while the thorax and abdomen have usually each their proper and normal series of seven free somites, with a corresponding pair of limbs attached to each segment.

Most of the members of this order are of small size, with a laterally compressed body; but their numbers are almost incredible, and they are most widely distributed not only in freshwater lakes and rivers, springs and subterranean watercourses, but they are found living along the shores of almost every land in the open air[1] and also between high and low tides.

[1] Some species of *Orchestia* are known (as *O. tahitiensis*, *O. telluris*, *O. sylvicola*) which live far removed from the sea and at elevations of 1000 feet.

In 1870 I described what I believe to be a portion of a fossil Amphipod from the Lower Ludlow Rocks of Leintwardine, Shropshire, under the name of *Necrogammarus Salweyi*; it is not quite certain whether *Gampsonyx fimbriatus*, Jordan, from the Coal-Measures of Rhenish Prussia, is correctly assigned to this division, but I am inclined to retain it here, however, as its most natural position. Mr. Spence Bate has named and described a species of Amphipod as *Prosoponiscus problematicus*, from the Magnesian Limestone of Durham.

Other fossil forms occur in the Tertiary rocks and are mostly referable to existing genera such as *Gammarus*, *G. œningensis*, from the Miocene of Œningen; and *Palæogammarus sambiensis*, from the Baltic amber deposits, etc.

Isopoda.—This division of the Malacostraca is marked by the persistence of the seven pairs of ambulatory thoracic limbs, which never bear the gills attached to their bases as in the Amphipoda, but the appendages of the abdomen take on this function, being specially modified into leaf-like branchial organs and do not take part in locomotion, save in the swimming forms. The members of the group are for the most part of small size. Many of the living Isopods are attached to fishes and crustacea, and one parasitic fossil form is known (*Bopyrus*).

Numerically, the order is large and very widely distributed geographically, consisting of walking, running, and swimming forms; and lastly of sedentary parasitic forms—of these it is the female only which remains fixed, the male being often peripatetic in his habits, passing from female to female. Many Isopods—*e. g.* the Oniscidæ—live habitually on land, breathing air, which it is necessary should be fairly moist; hence they usually frequent damp situations, under decaying wood and leaves, and beneath stones. The Sphæromidæ frequent rocky shores, and run and swim with considerable agility. Many forms of Isopoda are strictly marine, some occurring at great depths (over 2000 fathoms). Some few Isopods have been met with of larger size than the average members of the group. One, dredged by Prof. Alexander Agassiz, during the cruises of the 'Blake,' from a depth of 955 fathoms on the north-east of the bank of Yucatan, and north of the Tortugas, named *Bathynomus giganteus* by Alph. Milne-Edwards, measures 9 inches in length by 4 in breadth, and far exceeds any other living species in size. Notwithstanding the vast depth from which *Bathynomus* was obtained, the eyes are well developed, but instead of being placed upon the upper surface of the head as in all known wandering Cymothoidæ,

they are placed below the frontal border of the head, at the base of the antennæ.

I formerly entertained a very strong conviction that it would be possible to show the derivation of the Isopoda by direct descent from the Trilobita; but the former have so very constant and definite a number of 21 body-segments—as indeed is the case in the Malacostraca generally—(namely, 7 somites in the head, 7 in the thorax, and 7 in the abdomen), whereas in the Trilobita (as is the case with the Entomostraca generally) the number varies greatly, from 4 or 5 up to 28 somites in the body, that I feel I must recant and give up this heresy at once, lest I should be excommunicated by some later Carcinologist, and my effigy and papers burnt, if not my person.

It is probable that the Isopoda date back to the Devonian, for I have, in 1870, described, under the name of *Præarcturus gigas*, a form which appears to be a portion of a huge Isopod from the Old Red of Rowlestone, Herefordshire.

Portions of similar large Arthropods, which have been named *Arthropleura ferox*, by Salter, and *A. armata*, by Jordan, have been obtained from the Coal Measures of Manchester, of Fifeshire, of Radstock, Somerset, and from Saarbrücken, Rhenish Prussia, so that we may justly hope soon to obtain a fuller knowledge of the true characters of this remarkable animal.

The anomalous form, known as *Bostrichopus antiquus* (Goldfuss) from the Devonian of Nassau, may perhaps be placed here, as possibly related to the Munnopsidæ.

Several species of *Palæocaris* (*P. scoticus*, *P. Burnettii*, and *P. typus*) have been described from the Coal Measures of Manchester, of Scotland, of Bohemia, and of Grundy County, Illinois, U.S.A.; from this last-named locality another genus, *Acanthotelson Stimpsoni*, closely resembling *Palæocaris*, has also been obtained by Messrs. Meek and Worthen. These larva-like forms were relegated, by the late Prof. J. D. Dana, to a group holding an intermediate position between the typical Isopoda and the Amphipoda, for which he proposed the name 'Anisopoda.'

Isopodites triasicus, Picard, from the Muschelkalk of Thuringia, is somewhat doubtful. An undoubted *Sphæroma*-like Isopod, from the Great Oolite of Northampton, has been described by me under the name of *Cyclosphæroma trilobatum*, in 1890.

The Lithographic Stone of Solenhofen, Bavaria, has yielded two genera of Isopodous Crustacea, described in 1839 by Count Münster,

and named *Urda* and *Reckur*. A third Solenhofen form has been more lately described by von Ammon as *Ægites Kunthii*.

The well-known and abundant *Archæoniscus Brodiei*, of Westwood, described in 1845, from the Purbeck of the Vale of Wardour, Wiltshire, closely resembles existing members of the family Oniscidæ, to which it probably belongs. Mr. Westwood added another species, *Archæoniscus Edwardsi*, from the Lower Purbeck of Durdlestone Bay, Dorset, in 1854.

We owe to Prof. Bell the discovery of the parasitic Isopod, *Bopyrus*, beneath the carapace of *Palæocorystes*, from the Cambridge Greensand, in 1862. The females of similar forms infest the carapaces of the common Prawn around our coasts at the present day.

Palæga Maccoyi, Carter, is from the Upper Greensand of Cambridge, and *Palæga Carteri*, H. Woodw., from the Grey Chalk of Dover. *Cymatoga Jazikowi*, Eichwald, from the Chalk of the Volga, completes the series of Cretaceous Isopods. Nearly allied to *Palæga Carteri* is *P. scrobiculata* from the Lower Oligocène of Haring, Tyrol.

The Eocene of the Paris Basin and the Isle of Wight has yielded four species of the genus *Eosphæroma*[1]; *Sphæroma Catulloi* is from the Eocene of Italy; and one occurs in the Miocene of Bonn. Sismonda, in 1846, recorded and figured a *Sphæroma* (= *Palæga*) *Gastaldi* from the Miocene of Turin; and Oswald Heer a species of Woodlouse (*Armadillo molassicus*) from the Miocene freshwater strata of Œningen. Five others (*Cymodocea sarmatica*, Andr.; *Sphæroma exors*, Eichw.; *Sph. faveolatum*, Costa; *Palæga anconitana*, Andr.; *Archæosphæroma Fricii*) are all Newer Tertiary forms.

A species of *Oniscus*,[2] a *Trichoniscus*, and three species of *Porcellio* are all described from the Amber-deposits of Tertiary age on the Baltic coast; and a fossil *Sphæroma* (*S. Burkartii*) has been described from Mexico by M. Barcena.

PHYLLOCARIDA and CUMACEA.—Standing on the border-line between the Malacostraca and Entomostraca are the PHYLLOCARIDA, represented at the present day by the genus *Nebalia*, which affords a connecting-link between the Phyllopoda and the Malacostraca (see my previous address, Feb. 15th, 1895, pp. lxxxiii & lxxxiv).

In the earlier of these ancient Silurian 'Pod-shrimps,' such as

[1] Namely, *Eosphæroma Smithii*, *E. fluviatile*, H. W., *E. Brongniarti*, Edw., *E. obtusum*, H. von Meyer.

[2] Namely, *Oniscus convexus*, Koch, Tertiary amber-deposits, Baltic. *Trichoniscus asper*, Menge, loc. cit. *Porcellio notatus*, Koch, *P. granulatus*, Menge, *P. cyclophorus*, Menge, loc. cit.

Ceratiocaris papilio, *C. stygia*, and *C. Halliana*, the carapace is large and is composed, as in the living *Nebalia*, of a reduplication or fold of the dorsal integument of the head-segments, which stretches backwards and forms a separate cover or shield, not only to the cephalic and thoracic segments but even to some of the abdominal ones as well.

In some of the later forms, more particularly in species like *Ceratiocaris scorpioides* and *C. elongatus*, described and figured by Mr. B. N. Peach, F.R.S., from the Lower Carboniferous rocks of Eskdale, the carapace is quite small and only about one-fourth the length of the body, leaving about 10 segments of the slender thorax and abdomen exposed to view.

This is precisely what one sees in the living forms of the genera *Cuma*, *Bodortia*, *Diastylis*, etc., and one is led to the conclusion that we have here, in all probability, a passage upward from the more ancient Phyllocarid type (in which a larger expansion of the head-shield and a larger number of post-cephalic segments exist), to the more modern Cumacea (in which only a small dorsal shield is developed, formed partly by connecting some of the anterior thoracic terga with those of the head), and thus gradually leading up to the Decapoda (in which all the thoracic terga unite with the head to form a true cephalothoracic carapace as in *Astacus* and *Homarus*).

PODOPHTHALMA.—1. The STOMATOPODA—represented at the present day by *Squilla* and five other genera—are of especial interest to us as, they offer so many important points of difference in their structure from other adult crustacea. It is in this sub-order that the typical number of 21 segments can always be distinguished. The carapace is quite small, and only covers a part of the cephalothorax, while the gills are carried exposed in tufts attached to the abdominal swimming-feet. The second maxillipeds—usually small mouth-organs—are developed in *Squilla* into a pair of large and powerful raptorial claws, taking the place of the chelate limbs of the common lobster and crab.

From their extensive distribution over the seas of the globe, their past life-history and high antiquity, the Stomatopoda justly challenge the attention of the palæontologist.

They make their appearance as far back in geological time as the Coal Measures[1]—one species, *Necroscilla Wilsoni* (H. Woodw.),

[1] There is a doubtful form (*Amphipeltis paradoxus*), Salter, occurring in the Devonian of St. John, New Brunswick, which may belong to the Stomatopoda.

having been met with in the Middle Coal Measuresof Cossall, near Ilkeston, Derbyshire, by Mr. Edward Wilson, F.G.S., in 1876.

It is highly probable that *Diplostylus Dawsoni*, Salter (1863), from the Coal Measures of Nova Scotia, was related to *Necroscilla Wilsoni*, but it does not appear to have possessed appendages to the penultimate body-segment as seen in the latter genus.

The remarkable genus *Pygocephalus*, represented by *P. Cooperi* and *P. Huxleyi*, from the Coal Measures of Shropshire, Lanarkshire, etc. offers characters common to the Stomatopoda, the Decapoda, and the Schizopoda, showing clearly the narrowness and artificiality of our classifications, which must ever need to be enlarged, in order to embrace all the varied forms which now live or have existed in past times.

Small, but well-preserved, specimens of Crustacea, belonging to the genus *Squilla*, described by Count Münster, in 1839, as *Sculda pennata*, are known from the Lithographic Stone of Solenhofen in Bavaria. They differ little (save in the spinose ornamentation on the abdominal and caudal segments and appendages) from the existing species of *Squilla*.

The Cretaceous deposits of Hakel, in the Lebanon, have yielded to the patient labours of the late Rev. Professor E. R. Lewis, F.G.S., of the Syrian Protestant College, Beirût, a well-preserved fossil *Squilla* which I described and named, in 1879, as *S. Lewisii*, after that enthusiastic geologist. A *Squilla* from the same locality (in 1886) has been named *Sculda syriaca* by Dames. Schlüter has named two species, *Pseudosculda lævis* and *Squilla cretacea*, from the Chalk of Westphalia.

Another fossil example met with was obtained from the London Clay of Highgate by the late Mr. N. T. Wetherell, F.G.S., and was described and figured by me, in 1879, as *Squilla Wetherelli*. Lovisato (1894) has recorded a *Squilla miocenica* from the Miocene of Sardinia. These Secondary and Tertiary *Squillæ* all closely approximate to existing forms of Stomatopoda, but the ancient Carboniferous representatives of this sub-order suggest a more generalized type of structure than those of later times.

Notwithstanding their wide distribution in time and space, the Squillidæ are of rare occurrence—both recent and fossil. Two causes may probably assist in explaining this: first, the thinness of the test, which would render it less likely to be preserved; and secondly, the fact that all the species are fossorial in their habits, forming

a very deep, nearly vertical, cylindrical burrow: this goes down for several feet into the sand, which is hardened by the pressure of the dorsal surface of the animal's body. They thus, too, often escape capture by collectors in the living state, and are too delicate to preserve well when fossil.

2. The SCHIZOPODA,—represented at the present day by *Mysis*, and numerous other allied genera,—occupy the most primitive position in the order Podophthalma, and still retain unchanged the original characters which distinguished the progenitors of the group in earlier times.

This is further emphasized by the fact that many Decapod Crustacea, in their more-advanced larval stages, pass through a '*Mysis*-stage' before reaching the adult condition.

Eight pairs of similarly-formed thoracic limbs are present (namely, three pairs of maxillipeds, and five pairs of posterior appendages), each being furnished with a well-developed exopodite and endopodite, and frequently bearing freely-projecting external gills, not covered by the cephalothoracic shield.

Considering the greater simplicity of the forms in this division, it seems highly probable that some of the earliest Macruran Crustacea, such, for instance, as the *Palæocrangon socialis* of Salter, from the Coal Measures of Fifeshire, may have belonged to the Schizopoda, but very few of these are sufficiently well-preserved to render exact determination possible.

Such forms as *Udorella Agassizi*, Oppel, from the Lithographic Slate of Kelheim, Bavaria, in which the cephalothoracic shield is short, and the legs uniform and provided with endopodite and exopodite, may, I think, with almost absolute certainty be referred to this division.

MACRURA.—The earliest example known of this modern division of Crustacea was obtained by Prof. R. P. Whitfield, in 1880, from the Erie Shales (Upper Devonian), Le Roy, Lake Co., Ohio, U.S.A., and named by him *Palæopalæmon Newberryi*, which in its general characters closely resembles the modern Crangonidea, the Shrimps and Prawns.

To this division must also be referred the *Palæocrangon eskdalensis* of Peach (1880), from the Lower Carboniferous rocks of Eskdale, Scotland.

Eight species of *Anthrapalæmon* from the Coal Measures of Scotland and England; one from Illinois, U.S.A.; and one from

Nova Scotia, illustrate the abundance of these small crustacea in the Carboniferous period. They have many points in common, but probably deserve more than specific differentiation.

With the exception of *Anthrapalæmon Parkii*, *A. Traquairii*, and *A. Etheridgei*, which measure from 3 to 5 inches, the other species do not exceed 1 to 2 inches in length.

The carapace and body-segments were evidently and usually broadly expanded, as in the Eryonidæ; the large scale at the base of the outer antennæ suggests the Penæidæ; the strong basal joints of the inner pair of antennæ with bifid flagella, and the outer pair with single ones, are like many of the modern Caridea and Astacidea: the caudal appendages forcibly recall the rhipidina of the living Galatheidæ, in which, as in some ancient forms, there are two additional broad lamellæ to the tail-fan, developed one on either side of the telson. [This fact, as Peach correctly observes, strongly favours the view that the telson should not be treated as a mere median appendage, but as a true 21st body-segment.]

In the spinose ornamentation of the somites and caudal plates; in the broadening out of the segments of the abdomen and the short rounded form of the cephalothoracic shield (especially in *Anthrapalæmon Parkii*) one is reminded of the genus *Squilla*, but most probably this is only an analogy and nothing more. There is some evidence, though not quite satisfactory, that the branchiæ may have been partly exposed as in *Mysis*, but we need further light on this point.

Enough has been said, however, to show that the small Carboniferous Crustacea are much more generalized than their modern descendants, and probably stood in the position of great ancestors to most of the living Macrura and even to the Brachyura also.

The Caridea, embracing all the shrimps and prawns, and possibly also some of those ancient Carboniferous species of Anthrapalæmonidæ already referred to, are divisible into the Monocarpinea, the Polycarpinea, and the Crangonidea.

MONOCARPINEA.—In this section the fifth joint of the wrist of the second pair of thoracic limbs is not subdivided, and the chelæ of this pair are larger than those of the first pair.

The living representatives are divided into eleven families, the best known perhaps of which is that of the Palæmonidæ, embracing the true Prawns. In these the first and second pairs of thoracic

legs are chelate, the second being the longest pair; the carapace is even and rounded, with two points, the one above, the other beneath the peduncle of the external antennæ; the rostrum is of great length, curved upwards, and armed with 7 or 8 teeth above and 4 or 5 beneath; the inner antennæ have three filaments, two of which are long; the outer antennæ have filaments of very great length, and a long and pointed scale near the base. The oldest of this type known is the *Æger raiblana* from the Trias of Raibl, Austria. Two species of *Æger*, namely, *Æ. Marderi* and *Æ. Brodiei*, have been described by me from the Lower Lias of Lyme and of Warwickshire; five forms of the same genus have been figured by Münster and Oppel from Solenhofen, remarkable for the length of the rostrum and of their last pair of spinose pediform maxillipeds. The genera *Udora*, *Hefriga*, and *Elder*, from the Lithographic stone, probably all belong here.

Another Prawn, *Oplophorus van-der-Marcki*, Schlüter, is from the Chalk of Westphalia; two species of the genus *Homelys* (a freshwater Prawn) are from the Miocene of Œningen; *Micropsalis papyracea*, H. v. Meyer, from the Tertiary Paper-coal of Rott, near Bonn, and *Palæmon exul*, Fritsch, from the Tertiary of Bohemia, complete this tribe.

Polycarpinea.—This section embraces the families Nikidæ, Alphæidæ, Hippolytidæ, and Pandalidæ. All the members of this group are distinguished by one common character: it is, that the second pair of slender thoracic legs have the carpus, or fifth joint, multiarticulate—that is, subdivided into a greater or less number of minor joints, like the flagellum of the lobster's antenna.

It is interesting to record that this remarkable and multiversatile hand had already been in use, no doubt prior to the Upper Jurassic period, for the genus *Blaculla* had just such slender limbs of this pattern, one fourth longer than its entire body. Three species have been noticed by Oppel from the Lithographic Stone of Solenhofen in Bavaria; while 27 genera of world-wide distribution still illustrate the convenience of this form of limb, which may serve to assist this small Shrimp to extract, from spiral shells and slender worm-tubes, food of a nutritious and appetizing kind.

Crangonidea.—In *Crangon* the rostrum is absent or rudimentary; the inner antennæ have a dilated base terminating in two filaments; the external antennæ are nearly on the same line with the inner ones, and have a large scale at the base; the first pair of thoracic legs is subchelate; and the finger is inflected to meet a small

rudimentary thumb. The hinder margin of the carapace is overlapped at the sides by the first segment of the abdomen.

It seems probable that *Udorella Agassizi*, from the Lithographic Stone of Solenhofen, belongs here: the feet are monodactylous, but the outer antennæ each have two flagella, and the thoracic feet carry endopodites externally, which may be gills as in *Mysis*. *Pseudocrangon tenuicaudus*, from the Chalk of Westphalia, should, I think, be placed here.

The position of *Palæocrangon eskdalensis*, from the Lower Carboniferous of Scotland, is very doubtful.

Mesocrangon atra is from the Gault of Folkestone, and *Pseudocrangon* from the Chalk of the Lebanon.

The Penæidea, typified by the genus *Penæus*, are a group abundantly represented in the Secondary rocks. The oldest form is probably the *Penæus liassicus*, Oppel, from the Lower Lias, Schambelen, Switzerland, and next comes *P. Sharpii*, H. Woodw., from the Upper Lias of Northampton. There are, moreover, five well-preserved species, figured and described by Oppel from the Lithographic Stone of Solenhofen. *Acanthochirus* 3 species, *Bylgia* 3 species, *Drobna* 2 species, and *Dusa*? 3 species, are also considered to belong to the Penæidæ. *Penæus septemspinatus*, Dames, and *P. libanensis*, Brocchi, are from the Cretaceous of the Lebanon.

Penæus and 20 other genera allied to it are living at the present day very widely distributed geographically. The New South Wales species, *P. esculentus*, attains a length of 9 inches, and is largely used for food. The genus is of especial interest, not only as occurring fossil, or as being edible, but from the fact that, so far as we at present know, it is the only Macrurous Decapod in which the young passes from the egg as a simple *Nauplius*-larva, similar to that of a young Copepod, Cirripede, or Phyllopod-larva just hatched from the egg, and advances through a series of moults to a *Mysis*-formed zoea before attaining the adult stage.

Astacidea.—Of the section Astacidea, the Eryontidæ occupy the first family, but they are peculiar and vary considerably from the ordinary type.

Eryontidæ.—The genus *Eryon* was first made known by Desmarest in 1822, and was applied by him to a group of Macrurous Crustacea with a broad and flat carapace, strongly notched or indented around the anterior border, but with straight sides; the antennules are small, and bear multiarticulate flagella: there is a narrow scale near the base of each outer antenna, the flagellum being of moderate

length and stoutness. The abdominal segments are short and flat, but narrower than the carapace, and terminate in a rather pointed telson and 4 tail-laminæ. The first pair of thoracic legs are nearly as long as the body: all the limbs have chelate extremities, save the last pair, the extremities of which are simple.

It is not improbable that the earliest members of this ancient family (which attained its majority in the Upper Jurassic period) may be traced back as far as the Lower Carboniferous of Eskdale, Scotland; and they may be identified with such species as *Anthrapalæmon Macconochii*, *A. Woodwardii*, and some others (see Quart. Journ. Geol. Soc. 1879, vol. xxxv. pl. xxiii. p. 464) described by R. Etheridge, Jun. Another early form is the *Eryon raiblanus*, Bronn, sp., from the Trias of Raibl, Bohemia; followed by the *Eryon (Tropifer) lævis* of Gould from the Rhætic Bone-bed of Aust.

In the Lias formation there are ten described species, namely:—

Eryon Calvadosii, Morière, U. Lias, Caine, Calvados.
„ *Hartmanni*, Meyer, U. Lias, Wurtemberg.
„ *Edwardsi*, Morière, U. Lias, Calvados.
„ *Moorei*, H. Woodw., U. Lias, Ilminster.
„ *Escheri*, Oppel, L. Lias, Baden.
„ *antiquus*, Brodp., L. Lias, Lyme Regis.
„ *barrovensis*, M'Coy, L. Lias, Barrow-on-Soar.
„ *wilmcotensis*, H. Woodw., L. Lias, Wilmcote.
„ *Brodiei*, H. Woodw., L. Lias, Lyme Regis.
„ *crassichelis*, H. Woodw., L. Lias, Lyme Regis.

One species occurs in the Great Oolite (Stonesfield Slate), namely, the *Eryon Stoddarti* of H. Woodward, while the *Eryon Perroni* of Étallon occurs in the Oxford Clay of Calmoutiers, Haute Saône, France.

Ten species of *Eryon* have been described from the Lithographic Stone of Solenhofen (probably near the horizon of the Kimmeridge Clay of England), namely:—

Eryon propinquus, Schloth.
„ *spinimanus*, Germar.
„ *orbiculatus*, Münst.
„ *elongatus*, Münst.
„ *arctiformis*, Schloth.
Eryon bilobatus, Münst.
„ *longipes*, Fraas.
„ *Schuberti*, Meyer.
„ *Redtenbacheri*, Münst.
„ *Oppeli*, H. Woodw.

I have described one Lower Cretaceous species under the name of *Eryon neocomiensis*, from the Neocomian of Silesia.

Lastly, we are indebted to the Naturalists of the *Challenger* Expedition for a knowledge of several living representatives of

the family Eryontidæ, referred to the genera *Polycheles*, *Pentacheles*, *Stereomastis*, and *Willemoesia*, from the Mediterranean, the Atlantic, and the Pacific, obtained from depths varying between 220 and 1900 fathoms. The recent species bear a very close resemblance to their Liassic and Oolitic ancestors, and they offer a striking illustration of the vast length of time over which a family may extend with very little alteration as regards general form.

What is the reason for the remarkable fact that so many old-world genera, belonging to such varied forms as *Nautilus*, *Pleurotomaria*, *Pholadomya*, *Arca*, *Calveria*, *Pentacrinus*, *Polycheles*, etc., dating from the Mesozoic period rather than the modern one, should still be found living in the deeper waters of our present oceans? Are we justified in concluding that they have so survived because those areas have remained undisturbed since the close of the Permian epoch? Or have they been compelled to occupy the deeper waters by other and stronger forms of marine life?

The SCYLLARIDEA might, at first sight, appear to offer an analogy, in their broadly-expanded and flattened-out cephalothorax and abdomen, to the genus *Eryon*, but they are in reality very widely separated from that family (which are Astacidea), the broad and serrated front of the carapace in *Scyllarus*, *Thenus*, and *Ibacus* being largely due to the very singular modification of the great pair of outer antennæ, the joints of which are flattened out into enormously broad and spinous fan-shaped scales, the eyes being usually inserted in deep hollows near their bases at the outer anterior angles of the head, but in *Ibacus* they are set nearer the front centre.

These singular forms are recorded as far back as the Gault, two species having been noticed by me from that formation and named *Scyllaridia Gardneri* and *Scyllaridia punctata* (Geol. Mag. 1873). *Ibacus præcursor* of Dames is from the Chalk Rock of the Lebanon. Other species from the London Clay have been figured and described as *Scyllaridia Koenigii*, *S. Bellii*, and *Thenops scyllariformis*, all from the Isle of Sheppey.

It is interesting to record that the late Prof. von Seebach discovered and described a larval Palinurid from the Lithographic stone of Solenhofen, well known—among living Crustacea—as 'the Glass-crab,' *Phyllosoma*[1]; some of these *Phyllosomæ* have been proved to be the larval stages of the Scyllaridæ.

[1] Münster, 'Beiträge zur Petrefaktenkunde,' Heft i. p. 84, pl. viii. figs. 3, 4. 4to. 1839.

Prof. Dames has described and figured two supposed larval forms of Crustacea from the Cretaceous of the Lebanon, under the names of *Pseuderichthus cretaceus* and *Protozoëa Hilgendorfi*, which, in the long produced fore-and-aft spines on the carapace, call to mind the larvæ of *Hippa*, *Porcellana*, and of some other living Decapoda.

PALINURIDÆ.—In *Palinurus* the carapace is less expanded and is longitudinally subcylindrical, with the orbits partially excavated and the eyes protected by strong spines; the external antennæ are very thick and long, their basal joints strong and spinous. The internal antennæ are principally composed of three long joints, with two small flagella at their extremities. All the feet are monodactylous. The tail is very broad, and the outer lamella is not jointed.

Palinurina longipes, Münster, is found in the three divisions of the Lias of England, and in the Lithographic stone of Solenhofen, Bavaria, and other localities.

Palinurus (*Glyphæa*) *Sæmanni*, Oppel, sp., and *P. Woodwardi*, Fritsch, come, the former from Solenhofen, and the latter from the Chalk of Bohemia. *P. nanodactylus*, Schl., sp., is from the Chalk of Sendenhorst, Westphalia.

Cancrinus claviger and *Cancrinus latipes* make us acquainted with a very remarkable Palinurid from Solenhofen, in which the outer antennæ are developed into large multiarticulate club-shaped organs.

Here is also placed a singular crustacean with simple monodactyle thoracic limbs, from the Lower Lias of Barrow-on-Soar, Leicestershire, named by me *Præatya scabrosa*.

Archæocarabus Bowerbankii, M'Coy, carries the Palinuridæ on into the Eocene Tertiary strata, and the *Palinurus vulgaris* (or common 'Spiny' Crawfish) is living around the rocky parts of our own coasts and those of France and the Mediterranean, and elsewhere, abundantly to-day.

There are several fossil forms of long-armed monodactylous crustaceans which have been placed here, presumably for convenience; beginning with *Scapheus ancylochelis*, H. Woodw., from the Lower Lias of Lyme Regis (Quart. Journ. Geol. Soc. vol. xix. 1863, pl. xv.); *Mecochirus Pearcei*, M'Coy, and *M. socialis*, Meyer, sp., from the Oxford Clay of Christian Malford, Wiltshire; *Mecochirus Peytoni*, H. Woodw., from the Kimmeridge Clay, 'Sub-Wealden Boring,' Sussex; and represented by six long-armed species from the Lithographic Stone of Solenhofen Bavaria. These singular forms were

probably all of them burrowing species, using their long arms to assist them in the process.

GLYPHÆIDÆ.—This family is represented by the genus *Pemphix*, and appears first in the Muschelkalk of Crailsheim, Germany. It approaches somewhat the modern *Palinurus* in character: Desmarest, who first described it, in 1822, placing it in that genus. It has a strongly-marked warty carapace, large outer antennæ, and the first pair of thoracic legs are monodactylous. A number of small carapaces referred to *Palæopemphix* by Prof. Gemmellaro, of Palermo, have been figured and described by him from the *Fusulina*-Limestone of Sicily as *P. sosiensis*, *P. affinis*, and *P. Meyeri*; but no appendages have been found with these carapaces.

Many forms, referred to the genera *Glyphæa* and *Pseudoglyphæa*, with the regions of the cephalothorax strongly accentuated, and having monodactylous thoracic feet, occur in the Jurassic rocks of this country and of Solenhofen, while species of *Glyphæa* and *Meyeria* occur in the Greensand and Chalk of England and Bohemia.

ASTACIDEA.—As several of the characters attributed to this tribe are certainly applicable to some, if not to all, the small forms referred to *Anthrapalæmon* in the Carboniferous Period, we are probably justified in considering this as the more generalized ancestor of all the Astacidea.

No fewer than 39 species of the genus *Eryma* occur from the Middle Lias to the Lithographic Stone (=Kimmeridgian), while *Astacus*, *Pseudastacus*, *Hoploparia*, *Enoplaclytia*, *Palæastacus*, and other allied genera carry us through the Cretaceous and Tertiary series up to the recent *Nephrops* and *Homarus*, representing the marine branch, and to the Potamobiidæ and Parastacidæ, the former embracing all the freshwater forms of Crayfish in the Northern, and the latter all those in the Southern Hemisphere.

In the Jurassic we also have:—

Eryma Villersii, Oxfordian, Calvados.

In the Cretaceous we have also:—

Pseudastacus hakelensis, O. Fraas.
„ *minor*, O. Fraas.
Nymphæops coesfeldiensis, Schlüt., Chalk, Westphalia.
Cambarus primævus, Packard, Lower Tertiary, Wyoming.
Astacus politus of Schlüter, Chalk, Westphalia.
Homarus Bosquetii, Cretaceous, Maestricht.
„ *Percyi*, Rupelmonde, Brabant.
„ *Bredai*, Pels, Cretaceous, Maestricht.

The existence of this Astacomorphous type from Palæozoic times exactly corresponds with its remarkable and world-wide distribution at the present day. The late Prof. Huxley suggested that the descendants of *Eryma* in Jurassic times gave rise to *Enoploclytia* and *Hoploparia* in the Cretaceous period, and these to the modern marine Homarina: *per contra*—that *Pseudastacus*, in the Jurassic, originated the freshwater Potamobiidæ, which have, in the long period of time that has since elapsed, not only split up into the northern and southern potamobine and parastacine types, but have become distributed from land to land by overland and freshwater lines of communication, since broken up and removed, but which must, upon this hypothesis of descent, have formerly existed; unless we are prepared to adopt the theory of geographical distribution of animals, propounded by St. Augustine for insular floras and faunas—namely, that they were carried there by angels.

The magnitude of the problem of the Astacidea becomes more apparent when we bear in mind that these freshwater Crayfishes are distributed over the rivers and lakes of 12 widely separated and extensive land-areas (each being marked by its own geographical species), such as the European-Asiatic area, the Amurland, the Japanese, the West North American and the East North American, the Brazilian, the Chilian, the New Zealand, the Fijian, the Tasmanian, the Australian, the Madagascar areas.

It is not without interest to observe the strong cousinly resemblance between many of these forms now separated so far by time and space. Take, for instance, two of the largest living forms—the *Astacoides madagascariensis*, from Madagascar, and the *Astacoides armatus*, from the Murray River, South Australia; they closely resemble one another in form and in general structure, although now separated by the breadth of the great Indian Ocean; but the former species is smooth, or only slightly scabrous, while the latter, as its name suggests, is armed with prickly spines on the sides of the cephalothorax and the abdominal somites.

This spinose ornamentation may seem trivial, but it is, I believe, unique of its kind among living Astacides. Strange to say, it finds its homologue not in another living or fossil form of Crayfish, but in an ancestor of the marine branch of the Astacidea, the *Enoploclytia sussexiensis* from the Chalk of England.

The Thalassinidea form a remarkable family of true fossorial Macrura, having a long and slender abdomen, the segments of which do not overlap, and the epimera are feebly developed; they have also

a small carapace, compressed on the sides; the eye-stalks are small; both pairs of antennæ have long peduncles. The first pair of legs are imperfectly chelate and expanded for digging at their extremities, the others are shorter and hirsute. The swimming-plates of the tail are slender and pointed.

The Thalassinæ are common on the west coast of Australia and in the Fiji Islands, and always inhabit deep burrows, which they excavate in the sand or mud near low water. One fossil species, *Th. Emeryi* (Bell), has been described by Prof. Bell from Western Australia, where *Th. scorpioides* is found living.

The genus *Callianassa* (belonging to the same family) occurs on the coasts of Ireland, Britain, France, and the Mediterranean, the shores of North America, and elsewhere. The carapace is small, without a rostrum; the abdomen large; the integument is not very firm. The front legs are large and strong, one hand being very much more developed than the other; the third pair of legs are wide near the end, and are used by the animal in digging.

This lobster lives habitually concealed in its burrow with only its strong chelate fore-limbs projecting, ready to seize on any passing prey. As a result of this habit, perfect specimens are seldom to be obtained, but the great claws are frequently to be seen, both recent and fossil, in Museums.

A species of the genus *Callianassa* is met with in the Kimmeridge Clay; one species occurs in the Cretaceous of North America, ten in that of Europe, and one in the Eocene of the Isle of Wight. So far as one is able to rely upon the imperfectly preserved fossil remains, it would appear that the species of this genus have undergone but little change, and occupy to-day the coasts of relatively the same areas in which their fossil remains have been found as far back as the Upper Jurassic.

Upogebia (=*Gebia*) is an equally active burrowing form, and closely related to *Callianassa*, from our own shores and those of North America. Passing over the Axiidæ, also closely related, we come to the Thaumastochelidæ, established for the genus *Thaumastocheles*, a very remarkable burrowing form dredged from 450 fathoms and more, off St. Thomas, in the West Indies, by the *Challenger* Expedition. It is very like the Callianassidæ in general appearance, but one of the hands is modified into a very strong claw, armed with a long, slender, and delicate forceps-like chela provided with slender and very numerous teeth. This curious burrowing form of Crustacean (*Thaumastocheles Zaleucus*), living now in deep water

off the West Indies, is represented by two almost identical forms, described by Prof. Dr. Anton Fritsch, namely, *Stenocheles esocinus*, Fr., and *Stenocheles parvulus*, Fr., both from the Chalk of Bohemia. *Ischnodactylus inæquidens*, Pelseneer, from the Uppermost Chalk of Limburg, belongs apparently to the same group of Crustacea.

Is *Thaumastocheles Zaleucus* a deep-water survival from the Chalk-sea of Europe, and did its area extend to the West Indies?

Dr. Paul Pelseneer has figured and described a cephalothorax of *Galathea* (named *G. Ubaghsi*) from the Maestrichtien or Upper Chalk of Limburg, and I have received from Miss Caroline Birley another example of the same genus from the Danien Upper Chalk of Faxoe.

Brachyura (*Crabs*).—Standing between the long-tailed Lobsters (Macrura) and the short-tailed Crabs (Brachyura) is an anomalous group of forms, of considerable extent among living Podophthalma, fortunately, but few of which are met with as fossils. These were formerly elevated into the rank of a distinct tribe, the 'Anomura,' but a careful consideration soon reveals the fact that this name, like some still in use in other zoological groups, is but the confession of our ignorance as to the exact position of the individuals relegated to such scientific dust-bins.

G. O. Sars has made an earnest effort to clear up the relations of some of these Anomura, and, from a study of their larval stages, he is led to refer to the Macrura the following forms, namely:—*Lithodes*, *Eupagurus*, *Anapagurus*, *Munidopsis*, *Galathea*, *Munida*, and *Porcellana*. Of these, *Porcellana* and *Lithodes* heretofore had been placed on the side of the Brachyura, but, tested by their larval stages, they are really Macrura. On the other hand, the Dromidæ, Homolidæ, Raninidæ, and Dorippidæ belong to the anomalous forms of Brachyura. Such 'borderland' genera are among the familiar difficulties known to every zoologist in the study of any natural order, even when fossil forms are not, as in the present instance, taken into consideration.

In this anomalous group we are frequently enabled to penetrate the veil which Nature too often spreads over her workings, and to discover the secret of the transformation in appearance which many of these adult crustacea assume, and detect how it has been brought about.

Thus we find that all those forms which constantly hide themselves in burrows, or in shells of dead mollusks, living sponges, sea-anemones, and other like hiding-places, become in time quite

warped and distorted from their natural shape, by their mode of life, and lose the use of certain members, which cease to grow, while others develop peculiarities in structure, or they may, as in the Soldier-crabs, lose the hard coverings to their bodies. '*Dromia* does not carry about with it a turbinated shell, like *Pagurus*, but clothes itself in the bright skin of its victim, a sea-lemon (*Doris*), for example, or encourages a parasitic sponge of showy colour to grow upon its back, holding it in its place with its two hind pairs of rudimentary feet, just as the other true hermit-crabs hold their shells on over their soft-skinned bodies' (Gosse).

Species of *Dorippe* from Singapore have been observed by Dr. Archer, carrying the leaf of a mangrove-tree over their backs, or the half of a dead bivalve shell, to conceal them from view.

Specimens of *Hyas* not only dress themselves in living seaweeds, which they deliberately plant upon their backs, but if their surroundings be changed they will remove these, and replace them with some others more suitable in colour—to match with their new conditions.

In those forms which, like *Hippa*, *Ranina*, *Zanclifer*, and others, are expert diggers, the body and legs are both specially modified, enabling the animal to sink down rapidly backward into the wet sand, or soft mud, and so escape from capture.

Fossil Forms.—Of some of the oldest forms referred to this division there is considerable doubt, owing to want of more complete fossil evidence.

Thus, it is not easy to determine the true nature of the genus *Oonocarcinus*, of which Prof. Gemmellaro has figured and described three species from the *Fusulina*-Limestone of Palermo, Sicily.

With these doubtful forms is associated another, named *Paraprosopon Reussii*, Gemm., which is certainly referable to the genus *Cyclus*.

It is possible that *Oonocarcinus* may be part of an Arachnid, a supposition which its ornament suggests. This is certainly the case with regard to a supposed Brachyurous Crustacean, described by me, in 1878, under the name of *Brachypyge carbonis*, from the Coal Measures of Mons, Belgium. It proves to be almost certainly the abdomen, not of a Crab, but of an Arachnid near to *Eophrynus Prestvici*, H. Woodw., from the Coal Measures of Dudley (Geol. Mag. 1871, p. 385).

In 1866 I had the pleasure of describing a short-tailed crab,

from the Forest Marble of Malmesbury, Wiltshire, under the name of *Palæinachus longipes* (Quart. Journ. Geol. Soc. vol. xxii. 1866, pp. 493–4, pl. xxiv. fig. 1), which is still the oldest fossil crab known.

As the limbs are preserved, as well as the carapace, its determination is all the more satisfactory and reliable. The legs are extremely long and slender; in this respect, and also in their form and in that of the carapace, with its remarkable prominent tubercles in front, it closely resembles the common 'Spider-Crabs'—the Maiidæ and Leptopodidæ—living on our own coasts at the present day, and the great Japanese Crab, *Mecocheirus Kempferi*, of De Haan. In 1868, I figured and described the carapace of another Brachyuran Crustacean, but without limbs attached, from the Great Oolite of Stonesfield, under the name of *Prosopon mammillatum* The Upper White Jura of Ulm, Germany, has yielded carapaces of several minute crustacea, which are either Brachyurous or Anomurous; these are generally placed under the Dromiacea, but unfortunately no limbs or abdominal segments have been found associated with them. As many as 3 genera and 26 species of these forms have been figured and described by H. von Meyer, Quenstedt, and Reuss.

Although short-tailed or Anomalous Crabs are rare in the Jurassic Series, they become more abundant in Cretaceous times, and we find not only the earliest and simplest forms, such as Dromiacea, but also representatives of all the great families of the Brachyura.

Commencing with the Dromiacea, we find a genus, like *Dromilites*, which I have named *Prosopon Etheridgei*, occurring in the Cretaceous of Queensland, Australia; *Cyphonotus incertus* and *Plagiophthalmus oviformis*, from the Greensand of Cambridge and of Wiltshire; *Diaulax Carteriana*, from the Cambridge Greensand, and *D. feliceps*, from the Gault, Folkestone; *Platypodia Oweni*, from the Chalk of Sussex; *Polycnemidium pustulosum*, from the Chalk of Bohemia; *Glyphithyreus formosus*, from the Pläner-Kalk of Ebendort; *Dromiopsis rugosa*, from the Chalk of Faxoe; and *Homolopsis Edwardsi*, from the Gault and Greensand of England.

Dromilites Lamarckii, of Desmarest, and *Goniochele angulata*, of Bell, are both London Clay forms from the Isle of Sheppey; *Stenodromia* is from the Eocene, Biarritz. These complete the Tertiary record, while about 9 genera and numerous species are widely distributed over the seas of the world and are still living.

In the RANININEA we have *Raninella elongata* and *R. Mülleri*, from the Cretaceous of Aachen; *Raninoides lævis*, from the Chalk of Osnabrück; and *Ranina cretacea*, Dames, from the Lebanon. From the Eocene we have *Notopus Beyrichii*, Bittner, and *Palæonotopus Barroisii*, Brocchi, from the Paris Basin; *Ranina Marestiana*, König, *R. speciosa*, Münst., and *R. bavarica*, Ebert, from the Eocene, Kressenberg, Bavaria, and *R. Bouilleana*, Milne-Edw., from the Eocene, Biarritz; *Ranina Adamsii*, H. Woodw., from the Miocene of Malta; *R. palmea*, U. Tertiary, Asti, Piedmont; *R. speciosa*, Tertiary, Bünde; *R. oblonga*, from Ebenda; whilst *Ranina scabra* (vel *dentata*), from Amboina, *Raninoides personatus*, *Notopoides latus*, *Notopus dorsipes*, *Lyreidus tridentatus*, *L. Bairdii*, and *Zanclifer caribensis*, live at the present day on various subtropical coasts.

This concludes all that I have to say regarding the Anomalous Brachyura.

In the OXYSTOMATA, or 'sharp-mouthed' crabs, which derive their tribal name from the more or less triangular shape of the buccal region, the carapace is convex, with the antero-lateral margins arcuate, orbiculate, subglobose or more or less oblong—in fact variable in form. These are represented among living forms by the Dorippidæ, the Calappidæ, the Matutidæ, and the Leucosidæ.

The DORIPPIDÆ are certainly anomalous forms although placed in this division, and would seem more suitably located with the preceding group. The carapace is very broad behind, with projecting abdominal somites as in *Dromia*—the last two (4th and 5th) pairs of legs being short and feeble with strongly hooked extremities, and carried rather on the dorsal surface—the chelipeds are small, while the 2nd and 3rd pairs of ambulatory legs are long and adapted for running. The weak and small 4th and 5th legs are probably used to carry foreign objects on the back for the purpose of concealment, as noticed by Surgeon-Major Archer at Singapore.

In the CALAPPIDÆ the carapace is narrow but deep in front, and expanded behind into thin, broad, shield-like expansions which cover and conceal the bases of the walking-legs. The chelate fore-limbs are very flat and strongly crested, like a cock's-comb, and when pressed close to the carapace they meet in front and form an efficient shield to the body.

In the MATUTIDÆ, represented by *Matuta victor*, the 3rd, 4th, and 5th pairs of limbs are suitable either as paddles or for burrowing in the wet sand, in which they are very expert.

The Leucosiadæ are small, well-marked crabs, with rather long chelipeds and a rounded helmet-like carapace, sometimes polished or covered with minute tubercles, the small eyes being inserted deeply and near together on the front of the blunt projecting rostrum: 3 or 4 joints of the abdomen in the female are coalesced into a broadly rounded convex plate, on the inner concave side of which the eggs are carried and concealed.

The Oxystomata form the first division of the true Brachyura represented in the Cretaceous formation by at least 9 genera, commencing with *Necrocarcinus senonensis*, Schl., *N. Woodwardii*, Chalk, Westphalia, and *N. tricarinatus*, H. Woodw., from the Greensand; followed by *N. avicularis*, Fr., and *N. perlatus*, Fr., from the Chalk of Bohemia: thence we pass on to *Orithopsis Bonneyi*, Carter, Greensand; and to *Orithya Bechei* from the Gault, Folkestone, and *O. Woodwardi* from the Chalk Marl, Isle of Wight. *Trachynotus sulcatus*, Greensand, Wiltshire, and *Mithracites vectensis*, Isle of Wight, with *Hemioon Cunningtoni*, Greensand, Wiltshire and Cambridge, leading on to *Eucorystes Carteri*, Greensand, Cambridge, *Palæocorystes Broderipii* and *P. Stokesii*, Greensand and Gault, Folkestone. *P. lævis* is from Westphalia; *P. Callianassarum* and *P. isericus* come from the Chalk of Bohemia; *P. Normanii*, Bell, from the Chalk Marl, Isle of Wight; *P. Harveyi*, H. Woodw., from the Cretaceous of Vancouver Island, and *P. Mülleri* from the Chalk of Maestricht.

Passing upward into the Eocene Tertiary we have *P. glabra*, Eocene, Portsmouth, and *Cyclocorystes pulchellus*, Bell, London Clay, Holloway; *Mithracia libinioides*, Bell, and *Campylostoma matutiformis*, Bell, from the London Clay, Sheppey; *Hepatiscus pulchellus*, Bittner, Eocene, Northern Italy, and Egypt; *Calappilia verrucosa*, Eocene, Biarritz, and *Calappa*, sp., Eocene, Hungary; *Typilobus*, sp., Eocene, East Indies, and *Matuta*, sp., Eocene, Hungary.

In the Miocene and Newer Tertiaries we meet with *Atelecyclus*, Miocene and Recent; *A. rugosus*, Miocene, Montpellier; *Palæomyra bispinosa*, Miocene, Turin; *Calappa*, sp., Newer Tertiary and Recent. *Ebalia Bryerii*, Leach, Suffolk Crag and Recent; *Leucosia subrhomboidalis* and *L. cranium*, Newer Tertiaries and Recent; also *Ixa tuberculata*, post-Tertiary, East Indies. *Corystes Cassivelaunus*, the Masked Crab, is a recent example of the same family.

In the Oxyrhyncha, or 'sharp-snouted' crabs, represented by *Inachus*, *Maia*, *Hyas*, *Stenorhynchus*, etc., the carapace is narrow anteriorly and is usually provided with a pointed and bifid rostrum, the hepatic regions of the carapace being small and the branchial

regions large. The epistome is generally large, and the buccal region quadrate, with a straight anterior margin.

In long-bodied Crustacea the nervous system is divided into two parallel chords, with separate ganglia for each segment. In the Spider-Crabs the nervous system attains a high degree of concentration, there being only a thoracic and a cephalic ganglion, instead of about 15 separate centres, as in *Homarus*. Notwithstanding this high degree of cephalization, they do not display any great activity, but are generally of sluggish and slow-moving habits, their intelligence being principally directed to the arts of disguise and concealment in which they certainly display much ingenuity, especially in planting their backs and legs with seaweeds, corallines, *Alcyonia*, and the like, which they have been observed to change, from time to time, the better to suit the colours of their altered habitats.

This is undoubtedly one of the oldest tribes represented in geological time, being met with as far back as the Forest Marble (Great Oolite) of Wiltshire, and it disputes with the Dromiacea the ancestorship of all the short-tailed Podophthalma.

As before remarked, the earliest known crab is the *Palæinachus longipes*, H. Woodw., Forest Marble, Great Oolite, Malmesbury, Wiltshire. This is followed by *Lissiopsis transiens*, Fr., from the Chalk of Bohemia.

Lambrus nummuliticus, *Periacanthus horridus*, and *Micromaja tuberculata*, of Bittner, are all from the Eocene of Vicentino and other districts of Northern Italy.

Micromithrax holsatica, from the Miocene of Holstein, a species of *Maija* from the Miocene of Malta and another from the Coralline Crag of Suffolk, complete the list of the sharp-nosed crabs.

CYCLOMETOPA.—The crabs which are placed in the tribe of the Cyclometopa have the carapace arched in front and often broader than long; more rarely it is quadrate, or suborbicular, but in none of the members of this division is the carapace rostrate. It includes the Cancridea, Cyclinea, and Thelphusinea. [The Corystinea I would prefer to place with the Oxystomata.] Here is located that most ancient and astronomical genus—*Cancer*, with *Xantho*, *Ozius*, *Trapezia*, *Carcinus*, *Portunus*, *Polybius*, *Podophthalmus*, *Thelphusa*, and many more well-known forms, several being largely eaten by mankind. Members of the Portunidæ occur in the Eocene, and of the Cancridæ as far back as Cretaceous times.

The Cyclometopa (circular-fronted crabs) of the division CAN-

CRIDÆ make their first appearance in the Cretaceous Series, with *Xantho Fischeri* from the Gault of Neuchâtel, and *Colaxanthus formosus* from the Upper Greensand (Cenomanian) of Le Mans, Sarthe.

Next we find *Xanthosia* (with 2 species) in the Upper Greensand of Wiltshire and Cambridge; *Etyus* (with 3 species from the same locality as *Xanthosia*, and one species from the Pläner-Kalk of Bohemia); *Plagiolophus formosus* from the Upper Cretaceous of Mecklenburg, and *Cancer* (with one species from Mecklenburg and 3 from the Chalk of Bohemia); *Xanthopsis minor*, Stolley, Middle Oligocene, Southern and Northern Germany. *Xanthopsis Dufourii*, A. Milne-Edw., Eocene; *Plagiolophus Wetherellii*, Bell, *Xanthilites* (1 species), *Necrozius Bowerbankii*, A. Milne-Edw., *Xanthopsis* (with 4 species)—all from the London Clay of Sheppey; also 5 species of *Xanthopsis* and 1 of *Xanthelites* from the Nummulitic of Bavaria, of France, and Germany. *Etisus*, sp., is from the Nummulitic of the Landes, France.

Palæocarpilius has 6 species, found in the Eocene of Kressenberg, the Nummulitic of Verona, of Dax and the Gironde, and the Calcaire Grossier near Paris. *Harpactocarcinus* has 8 species from the Nummulitic of Italy, France, Spain, and New Zealand; and the genus *Neptunus*, with 8 species, comes from the Nummulitic of the Vicentino, of Sassari, and Montpellier, from the Miocene of Kutch, India, and from Malta.

Podophthalmus has only a single species, from the Tertiary; and *Syphax crassus* is known from the Nummulitic of Aude, France.

Eight species of *Cancer* occur in the Eocene of France, and in the Miocene and Pliocene of Italy, etc.

Phlyctenodes, with 2 species, is found in the Nummulitic of France, and one species in the Miocene of the Vicentino.

Eriphia spinifrons is from the Quaternary of Nice; *Galena obscura* from China; *Lobonotus sculptus* is known from San Domingo; *Palæocarpilius*, with 2 species, occurs in the Miocene of Kutch, India.

Atergatis, sp., has been obtained from the Miocene of Malta and *A. dubius* from that of Dax, Southern France.

A crab which delights in a very remarkable serrated front to his carapace and also enjoys the longest name extant—*Lobocarcinus Paulino-Wurtemburgensis*—occurs very abundantly in the Miocene beds of the Mokattam quarries near Cairo, Egypt.

Actæa persica is met with in the Newer Tertiary of the Isle of Kharu, near Bushire, Persian Gulf.

Zozymus Desmaresti is found in the Quaternary of Eastern Asia

Those of the section Portunidæ met with in a fossil state comprise:—*Carcinus peruviensis* from the Cretaceous, Peru, and *C. mænas*, subfossil, Jarrow Docks, Newcastle-on-Tyne; *Portunites incerta*, Bell, London Clay, Sheppey, and *Portunites*, sp., Miocene, Malta; *Titanocarcinus serratifrons*, from the Cretaceous, Ciply, Belgium; and five other species from the Nummulitic and Miocene of Italy and France; *Cyamocarcinus angustifrons*, Bittner, Eocene, Schio; *Goniosoma antiqua*, Milne-Edw.. Nummulitic Limestone, Salcedon, Northern Italy, and *Menippe Chauvinii*, Upper Eocene, Noyon, France. *Scylla Michelini* from the Miocene of Anjou, and *S. serrata*, Miocene, Malta, Quaternary, Philippines, and also living in the seas of the East Indies. *Goniosoma antiqua* and *Achelous obtusus* are from the Upper Eocene of the Vicentino. *Enoplonotus armatus* comes from the Miocene of Monte Bolca, and *Psammocarcinus Hericartii* is from the Lower Eocene of Meaux, France. *Rhachisoma bispinosa* and *R. echinata* (H. Woodw.) are from the Lower Eocene of Portsmouth.

The Catometopa have the front of the carapace bent downwards and broader in front, often subquadrate, but not rostrate. The epistome is short, often almost linear. Here are placed the Gecarcinidæ, the Ocypodidæ, the Grapsidæ, and the Pinnotheridæ. It is in this tribe that we meet with some of the most active and vigilant running forms of Crustacea—the 'Land-crabs,' which inhabit the warmer regions of the earth north and south of the Equator, and are able to respire moist air with their gills on land, as effectively as *Cancer*, *Polybius*, and others, breathe aerated water in the sea.

The swift-footed Sand-crabs (*Ocypoda*) are exclusively terrestrial animals, and can scarcely live for a single day in water; in a much shorter period, indeed, if kept in the water, a state of complete relaxation occurs, and all voluntary movements cease. Members of this tribe are met with as far back as the Cretaceous period.

In the Catometopa (represented by that interesting, active, and highly intelligent tribe the existing Land-crabs and Shore-crabs of subtropical regions) the fossil forms are not nearly so numerous as in the last division.

Commencing with *Podopilumnus Fittoni* from the Greensand of Lyme Regis, Dorset, and *Lithophylax* in the Chalk, we meet with *Litoricola glabra*, H. Woodw., and *L. dentata* in the Lower Eocene of Portsmouth (see Quart. Journ. Geol. Soc. vol. xxix. 1873, pl. ii.); *Œdisoma ambiguum*, in the London Clay of Sheppey; and an undoubted Land-crab, *Goniocypoda Edwardsii*, H. Woodw., from

the Eocene of High Cliff, Hants. A *Palæograpsus*, sp., is known from the Eocene of Northern Italy. *Colpocaris bullata* comes from the Nummulitic of Switzerland, *Cœloma vigil* from Vicenza, and *C. taunicum* from the Oligocene of Germany; *Cœloma rupeliense*, Stainier, from the Argile Rupelienne; *C. holsaticum*, Stolley, from Holstein. *Galenopsis crassifrons*, *G. Gervilleanus*, *G. pustulosus*, are all from the Nummulitic of Italy and France; and *G. Murchisoni* is from the Miocene of Sinde, India. *Mioplax*, sp., is from the Miocene of Radoboj, Austria. *Telphusa speciosa*, *T. Quenstedtii*, and *Gecarcinus punctatus* are from the Miocene of Œningen; *Glyptonotus trispinosus*, *Macrophthalmus Latreillei*, *M. emarginata*, *M. incisa*, and a species of *Gelasimus* are from the Island of Hainan, where they occur in the Quaternary deposits, and are collected largely for medicine by the Chinese druggists, in whose pharmacopœia they form an important item as an antacid and for the cure of sores.

In this group of Land-crabs we have two genera and species in the Cretaceous, ten genera and eleven species in the Eocene and Oligocene, and eight genera and nine species in Miocene and Newer Tertiary strata.

Last year I invited your attention mainly to the state of our knowledge of the earlier and simpler forms of Crustacea inhabiting the Palæozoic seas, and placed in the great division of the ENTOMOSTRACA. I referred to the extinct Trilobita and the important advance in our knowledge of this group which we owe to American palæontologists. I spoke of the MEROSTOMATA, including therein the Eurypterida and Xiphosura—the former aquatic division being now entirely extinct, but having, no doubt, given origin, in its remote ancestry, to the terrestrial and air-breathing Scorpionida, which have come down from the Silurian epoch to our time, apparently but little changed in structure—while the latter (the living *Xiphosura*, 'King-crabs') have even adhered, in both their general form and their aquatic mode of respiration and life, to their Palæozoic progenitors.

I discussed the Palæozoic 'giant Pod-shrimps,' Phyllocarida, placed heretofore with the general group of the Phyllopoda—now claimed as the direct ancestors of the modern Malacostraca—but still represented by one living form, apparently but little changed, —the genus *Nebalia*.

Of the other divisions of the Branchiopoda I said but little, nor

could I do justice to the Ostracoda and Copepoda, while as regards the Cirripedia, on which Charles Darwin laboured so long and exhaustively, I have been silent, because I found the whole subject of the Crustacea too large for the time at my disposal.

To-day I have attempted, in a very imperfect manner, to bring into the focus of my discourse a summary of the fossil Malacostraca, to which our modern Crustacea chiefly belong. It is true that the evidences of the existence of this division prior to the Mesozoic epoch are but few and scanty; nevertheless, even in Carboniferous times, if not in still earlier eons, we catch a gleam of the light of the living life-forms of to-day, shining clearly, though afar off, down the corridors of time, revealing ancestral forms, the prototypes of those which people so abundantly our modern seas, proving that the living present and the far-distant past are indissolubly linked together, and that the stream of life has flowed, from its parent source, through all time, at first in tiny rills and murmuring streamlets, yet ever growing stronger, 'from running brooks to rivers wide,' pressing ever and for ever, onward, from the river to the sea.

As to the minute details of the course which the evolution of Crustacean life has followed in past times, we can, in many cases, only infer, we cannot absolutely prove our proposition.

Thus we have no doubt that the aquatic Eurypterida gave rise to the terrestrial Scorpionida, but we cannot show any direct evidence, because we have *Eurypterus* and *Scorpio* side by side in Upper Silurian rocks, but the earlier evolutionary history is still wanting.

Again, *Nebalia*-like forms are most probably in the direct line of the ancestry of the modern Malacostraca, and in the Carboniferous period we have *Cumacea*-like forms, which have doubtless been derived from *Ceratiocaris* and have given rise to higher Malacostraca; but Macruran and other forms of Podophthalma and Edriophthalma were already in existence in the Devonian, and both Cumaceæ and Nebaliæ continue to exist unchanged at the present day.

Looked at broadly, however, the Crustacea show the same upward and onward development which marks other living forms whose history can be traced. The great extinct orders of Eurypterida and Trilobita have disappeared—the other Entomostracan orders have survived, but they no longer occupy the whole field: with the close of Palæozoic times the Malacostraca have developed in strength, and

now occupy the stage associated with the Tracheata proper, and the King-crabs and Scorpions, which latter, like the Ostracoda and Phyllopoda, are survivals from a pre-Silurian age.

Truly—

'The old order changeth, yielding place to new.'

My task is ended, and it now only remains my duty to efface myself officially, but before doing so I should like to express to the Council and Officers, and to the Fellows generally, my grateful sense of the honour which they conferred upon me when they placed me in this chair, and for the generous support and friendly forbearance which they have extended towards me in the performance of my duties. In this matter I cannot fail to recall how greatly I am indebted to the Secretaries and Treasurer, for the valuable assistance and advice which I have at all times received from them and from the permanent staff of the Society, without whose aid I could never have carried on the work devolving upon me.

In resigning the Presidential chair to my esteemed friend and successor, Dr. Henry Hicks, F.R.S., I feel that he is neither a stranger among us, nor inexperienced, for he has served as your Secretary for three years (1890–91–92), and has moreover had many years' experience on the Council of this Society.

May he thoroughly enjoy, as I have done, the two chief pleasures of office—that of taking the chair and that of resigning it. Farewell.

February 26th, 1896.

Dr. Henry Hicks, F.R.S., President, in the Chair.

William Griffith, Esq., Waterloo Hotel, Aberystwith, South Wales; Joseph Colin Francis Johnson, Esq., J.P., Adelaide, and Constitutional Club, London; Peter MacLaren, Esq., 352 St. Vincent Street, Glasgow; and Edwin Perkins Ridley, Esq., 6 Paget Road, Ipswich, were elected Fellows of the Society.

The List of Donations to the Library was read.

The following communications were read:—

1. 'On the Structure of the Plesiosaurian Skull.' By Charles W. Andrews, Esq., B.Sc., F.G.S.

2. 'On certain Granophyres, modified by the Incorporation of Gabbro Fragments, in Strath (Skye).' By Alfred Harker, Esq., M.A., F.G.S. (Communicated by permission of the Director-General of H.M. Geological Survey.)

3. 'Observations on the Geology of the Nile Valley, and on the Evidence of the greater Volume of that River at a former Period.' By Prof. E. Hull, M.A., LL.D., F.R.S., F.G.S.

4. 'The Fauna of the Keisley Limestone. Part I.' By F. R. Cowper Reed, Esq., M.A., F.G.S.

The following specimens, maps, and photographs were exhibited:—

Cast of Skull of *Plesiosaurus macrocephalus*, Buckland, exhibited by C. W. Andrews, Esq., B.Sc., F.G.S., in illustration of his paper.

Specimens of Granophyres from Strath (Skye), exhibited by Alfred Harker, Esq., M.A., F.G.S., in illustration of his paper.

Fossils from the Keisley Limestone of Westmoreland, exhibited by F. R. Cowper Reed, Esq., M.A., F.G.S., in illustration of his paper.

Human Skull, found about 6 feet beneath the surface, not far from the banks of the Wye, somewhat below the city of Hereford, exhibited by the Rev. J. O. Bevan, F.G.S.

Geological Survey of England and Wales, New Series, 1-inch Map (Solid and Drift) Sheet 249, Newport (Mon.), by A. Strahan and W. Gibson, 1895, presented by the Director-General of H.M. Geological Survey.

Photographs of Stratified Volcanic Ash at Tantallon Castle, and of Boulders from the Bagshot District, etc., exhibited by Horace W. Monckton, Esq., F.L.S., F.G.S.

March 11th, 1896.

Dr. Henry Hicks, F.R.S., President, in the Chair.

George C. Bond, Esq., Aspley House, Nottingham; Sydney Fawns, Esq., F.C.S., 16 Onslow Gardens, S.W.; and Dr. J. Shearson Hyland, 3 Copthall Buildings, E.C., were elected Fellows of the Society.

The List of Donations to the Library was read.

The President announced that, in connexion with the Hungarian Millennial Exhibition, a Congress of Mining and Geology would be held at Budapest on September 25th and 26th, 1896.

The following communications were read:—

1. 'On an Alpine Nickel-bearing Serpentine with Fulgurites.' By Miss E. Aston, B.Sc. With Petrographical Notes by Prof. T. G. Bonney, D.Sc., LL.D., F.R.S., V.P.G.S.

2. 'The Pliocene Glaciation, Pre-Glacial Valleys, and Lake Basins of Subalpine Switzerland; with a Note on the Microscopic Structure of Tavayanaz Diabasic Tufa.' By C. S. Du Riche Preller, M.A., Ph.D., F.G.S., F.C.S., A.I.M.I.E., M.I.E.E.

3. 'Notes concerning certain Linear Marks in a Sedimentary Rock.' By Prof. J. E. Talmage, D.Sc., F.G.S.

The following specimens, photographs, and maps were exhibited:—

Specimens and microscope-sections of Alpine Nickel-bearing Serpentine with Fulgurites, exhibited by Prof. T. G. Bonney, D.Sc., F.R.S., V.P.G.S., in illustration of the paper by Miss E. Aston and himself.

Specimens, photographs, and microscope-section, exhibited by C. S. Du Riche Preller, M.A., Ph.D., F.G.S., in illustration of his paper.

Specimens and photographs of Linear Marks in an Argillaceous Sandstone, exhibited by Prof. J. E. Talmage, D.Sc., F.G.S., in illustration of his paper.

Fossils from the Marine Permian of the Salt Range, India, exhibited by F. G. Brook-Fox, Esq., F.G.S.

And the following maps presented by the Austro-Hungarian Geological Survey:—Geologische Specialkarte der Umgebung von Wien, von Dionys Stur (in 6 sheets, scale $\frac{1}{75,000}$); Geologische Karte der östlichen Ausläufer der Karnischen und Julischen Alpen, von Friedrich Teller (in 4 sheets, scale $\frac{1}{75,000}$); and Geologische Karte von Olmütz, von Emil Tietze (scale $\frac{1}{75,000}$).

7. A Delimitation *of the* Cenomanian :—*being a* Comparison *of the* Corresponding Beds *in* South-western England *and* Western France. By A. J. Jukes-Browne, Esq., B.A., F.G.S., and William Hill, Esq., F.G.S. (Read January 8th, 1896.)

[Plate V.]

Contents.

I. Historical Introduction.

The object of this paper is to compare the beds which form the lower part of the Upper Cretaceous series in those parts of Western France and Western England which are nearest to one another. In England these beds are known by the names of Gault, Upper Greensand, and Lower Chalk; in France they are classed under d'Orbigny's 'Albien' and 'Cénomanien' stages. It is well known that in both countries the deposits referable to these groups change their lithological character so greatly, in passing towards the west and south-west, that different observers have formed different opinions in their attempts to correlate one area with another. Further, no geologist has yet endeavoured to make a careful comparison of the French and English types; but it is only by such a comparison that the true stratigraphical position of d'Orbigny's Cénomanien stage can be determined, and that the limits of this stage in areas outside the typical Cenomanian district can be fixed.

The name 'Cénomanien' was introduced by d'Orbigny in 1847 to designate the lower part of the series which he had previously called 'Turonien,' when he found that this lower portion contained a fauna essentially distinct from that of the upper part.[1] He then proposed to retain the name 'Turonien' for the upper part, and to adopt the name 'Cénomanien' for the lower part, taking the name from Le Mans, in the Sarthe, the *Cenomanum* of the Romans, and

[1] 'Paléont. Française: Terr. Crétacé,' vol. iv. p. 270. See also his 'Cours élémentaire de Paléontologie et de Géologie stratigraphiques,' 1852, vol. ii. p. 631.

regarding that district as the typical area of his new stage, because the deposits there were of considerable thickness and were rich in well-preserved fossils.

Unfortunately d'Orbigny himself fell into error regarding the deposits which should be included in his Cenomanian stage in the West of France. In the Sarthe there are no Lower Cretaceous strata, neither are there any beds containing a typical Albien fauna, so it is not surprising that d'Orbigny included the basal clays and greensands in his Cenomanian; but he also believed that his Albien stage was wanting near Havre, and that everything seen there above the Kimmeridge Clay was of Cenomanian age.[1]

This belief of d'Orbigny's was doubtless one cause which retarded the progress of opinion respecting the limits and components of the Cenomanian stage. Another cause is certainly to be found in the local and exceptional nature of the beds in the district which was chosen as the type, both as regards their lithological characters and the assemblage of fossils that they contain.

A study of what has been written by French geologists concerning the Cenomanian shows us that they have constantly found a difficulty in determining what beds in other parts of the country should rightly be regarded as the equivalents of the Cenomanian of the Sarthe.

In perusing the Vicomte d'Archiac's 'Études sur la Formation Crétacée'[2] we have been struck by the general accuracy of his correlations. He evidently had a masterly grasp of the subject and a keen eye for the structure of a country, and for tracing definite horizons in a changeful group of beds. He anticipates d'Orbigny in separating the 'groupe de la craie tufau' of Touraine and Anjou from his 'groupe du grès vert,' and he divides each of these groups into three stages. It is possible that he made some mistakes in the determination of his fossils, but the grouping of his beds appears to be more correct, stratigraphically, than the grouping adopted by d'Orbigny in his 'Cours élémentaire de Pal. et de Géol. stratigraphiques' of 1852. Certainly the comparisons made in his rapid traverse of the Sarthe, Orne, and Calvados are very correct, and we think that he laid a sufficiently accurate basis for a more detailed correlation of the Cenomanian deposits, if his successors had only worked along the same lines, and had not depended so entirely on the minutiæ of palæontological evidence.

Unfortunately the late Prof. Hébert, influenced probably by the statements of d'Orbigny, and struck by the differences between the Cenomanian faunas of Havre and of Le Mans, propounded the hypothesis that the greater part of the Cenomanian of the Sarthe, or Grès du Maine, as he called it, was newer than the 'craie glauconieuse' of Havre, and that the former was a local deposit which was not represented by anything on the northern coast. This was combated and disproved by M. Guillier and M. G. Bizet, who showed that chalky beds containing Rotomagian fossils occurred

[1] 'Cours élémentaire, etc.' vol. ii. pp. 619 & 635.

[2] Mém. Soc. Géol. France, sér. 2, vol. ii. pp. 1–148 (1846), published 1847.

in the midst of the Grès du Maine, and that the 'Rotomagien' or Rouen Chalk is merely the chalky facies of the upper part of the Cenomanian of the Orne and Sarthe. This view has been accepted by Prof. A. de Lapparent and by the officers of the Service de la Carte géologique de France.

French geologists, however, have not reached the end of the difficulties and controversies to which the local and isolated facies of their typical Cenomanian has given rise. They are even now at variance with regard to the line of separation between the Albien and Cenomanian stages. The Albien fauna of d'Orbigny was mainly that of the Lower Gault: the fauna of what we know as the Upper Gault and Blackdown Beds was by d'Orbigny included partly in the Albien and partly in the Cenomanian, under the mistaken impression that our Blackdown Beds represented a part of his Cenomanian.

Gradually, however, it became known that between the typical Albien and Cenomanian faunas there was a distinct zonal assemblage in the Upper Gault of Wissant, in the Gaize of the Ardennes, and in the Vraconnien of the Jura. The question then arose as to whether this zone of *Ammonites inflatus* should be included in the Albien or in the Cenomanian, and on this question French geologists differ to the present day, some thinking with Prof. de Lapparent that it should be classed as part of the Albien, others agreeing with Prof. Hébert and Dr. Barrois in regarding it as Cenomanian.

Further, Dr. Barrois's researches in England and in the North-east of France disclosed the existence of beds containing *Pecten asper* between the zone of *Ammonites inflatus* and the base of the Chalk in those regions. Now *Pecten asper* is a common shell in the Cenomanian of the Sarthe, and consequently French geologists are all of opinion that the true Cenomanian contains an equivalent of this zone of *Pecten asper*.

In England, as Dr. Barrois has shown, the Upper Greensand of Wiltshire, Hampshire, and Dorset may be divided into two zones, the lower being his zone of *Ammonites inflatus*, the upper being his zone of *Pecten asper*, which includes the chert-beds and green sands of Warminster and other places. The result of French investigation, therefore, has been to tell us that our subdivisions into Gault, Upper Greensand, and Lower Chalk do not tally in any way with their Albien and Cenomanian stages, and that if we wished to adopt the French nomenclature we should have to draw a hard-and-fast line in the middle of our Upper Greensand.

Having thus briefly indicated the history of French opinion, and mentioned the difficulties which have arisen in comparing the sections on each side of the Channel with the beds in the area which was selected as the typical facies of the Cenomanian stage, let us now as briefly indicate the progress of English studies in the same field.

It is to William Smith that we owe the nomenclature and primary classification of the English Cretaceous strata: he found in Wiltshire and elsewhere a succession of (1) clay, (2) and,

and (3) chalk, to which he gave the simple names of (1) The Gault, (2) The Greensand, and (3) The Chalk. His Chalk was subsequently divided first into Lower and Upper, and more recently into Lower, Middle, and Upper. For a long time the Gault and Upper Greensand were regarded as distinct formations or stages, but the tendency of modern opinion has been to consider them as different lithological phases of one formation or stage, and we have no doubt that a new name will have to be found for this combined Gault-and-Greensand stage.

The work of English geologists has therefore tended to consolidate the Gault and Greensand, and to separate them as a whole from the overlying Lower Chalk, which has generally a bed of glauconitic marl at its base, and is often marked off from the Upper Greensand by a very clear plane of division. The fossil assemblages agree with this method of classification, and no modern English geologist would imagine that a more natural division could be made by grouping a part of the Upper Greensand with the Lower Chalk.

This being so, it has for some time seemed odd to us that a different line of division should be taken by French geologists, and the question occurred to one of us whether they were fully justified in correlating the beds which they group as Cenomanian. This idea was greatly strengthened by a recent examination of the Devon coast-sections where the Upper Greensand is well developed, but the Lower Chalk is represented by a peculiar set of arenaceous beds which differ from anything else in England. The fauna of these beds is also peculiar. It includes *Pecten asper*, and many species which in England are only found in the Upper Greensand, others which are proper to the Lower Chalk, and some which have only hitherto been found in France. Both of us were struck with the similarity of this fauna to that of the French Cenomanian.

Having thus obtained what promised to be a key to the difficulty—for if *Pecten asper* occurred in a representative of the Lower Chalk in England, it might do so also in France—we proceeded to enquire how far this occurrence of *P. asper* might be responsible for the supposed necessity of grouping the Greensand zone of *P. asper* in the Cenomanian stage. We found that the succession of beds in the department of the Sarthe had been carefully worked out,[1] that the similar series in the Orne had been examined and described by M. Bizet, of Bellême, and that the Havre and Rouen sections had been described by Prof. Hébert, M. Lennier, and others, but that little or nothing was known about the intervening area in the Calvados. So far as we could learn, no one had published any detailed comparison of the succession in the Orne and Sarthe with the sections near Havre, and consequently it was uncertain how far south the Gault extended, and whether the base of the Cenomanian in the Orne and Sarthe corresponded with any definite horizon at Cape La Hève. This want of continuous stratigraphical information certainly seemed to leave much to be desired in the way of evidence,

[1] See Guillier's 'Géologie de la Sarthe.'

and suggested that more accurate views might be obtained by an investigation of some of the principal exposures along a traverse from the coast in the direction of Lisieux, Vimoutiers, and Mortagne.

In planning out the route of this traverse we owe thanks to M. G. F. Dollfus, of Paris, and M. Bizet, of Bellême, for advice and information regarding the best localities to visit. The cliffs between Cape La Hève and Etretat were first studied in detail, and subsequently two excursions were made to localities in the Calvados and Orne, between Honfleur and Mortagne.

[*Note.*—It should be mentioned that the examination of the French sections was accomplished entirely by Mr. Hill, and that the exposures in the Calvados had to be discovered without guidance, except so far as the outcrops were shown on the sheets of the Carte géologique détaillée de la France. The Devon coast-sections were worked out by myself in 1894 for the Geological Survey, and the Director-General kindly permits us to publish some of the information then obtained.—A. J. J.-B.]

In arranging our descriptive notes for comparison we have thought it best to place the English sections first, because this part of the Cretaceous series is much more complete, more frequently exposed in coast-sections, and more clearly divisible into two distinct portions or stages than it is in France. Consequently we feel justified in taking the English succession as a standard, and in endeavouring to bring the French succession into accord with ours. We believe that we have succeeded in doing this, and that as a result we shall have supplied French geologists with a better and more definite base-line for their Cenomanian stage. We think that the present state of confusion has arisen from their having adopted an opposite course, for they have taken a local and incomplete set of beds as a standard, and have tried to fit the more normal and complete succession with this unsuitable type. It is just as if we had taken the Devon type of these two stages as a standard, and had endeavoured to correlate the Gault and Lower Chalk of Folkestone with that local and peculiar type—without studying the intervening exposures.

II. A brief Description of some Sections on the South Coast of England.

The sections which most clearly exhibit the relationship of the Gault, Upper Greensand, and Lower Chalk are those on the coasts of the Isle of Wight, Dorset, and Devon.

1. Isle of Wight.

The stratigraphic succession of these groups in the Isle of Wight is fairly well known on both sides of the Channel, to the French from the writings of Dr. Barrois, and to us from those and from the second edition of the Geological Survey memoir on the island; so that we need only call attention to such points as have a special bearing on our present purpose.

In the first place, it is worthy of note that all the component members of the Cretaceous system are thicker here than at any other place along the south coast. Taking the Gault and Upper Greensand together, they have a thickness of 270 feet at Gore Cliff and of about 230 at Compton Bay, while the Lower Chalk is 200 feet thick near Culver Point, and is probably but little less at Compton Bay.

In the next place, no hard-and-fast line can possibly be drawn between the Gault and Upper Greensand; there are a set of passage-beds, sandy micaceous clays, which have been referred to the Gault by some authors and to the Greensand by others. As *Ammonites rostratus* was obtained from these sandy clays by the Survey fossil-collector, it would appear that they belong to the same zone as the overlying micaceous sands, and should not be referred to the Lower Gault.

Whether these passage-beds be included in Gault or in Greensand, it is equally impossible to take a definite base-line for the zone of *Ammonites rostratus*. There is the same kind of passage in other parts of England, and so long as the *Amm. rostratus*-beds are regarded merely as a zonal subdivision of the Gault-and-Greensand group there is nothing surprising in it. Dr. Barrois has taken the base of the yellow sands near Ventnor as the base of the Cenomanian stage in England,[1] but the bed of sandstone which there forms a convenient base-line has not been detected in other parts of the island. His endeavour to fix the base of the zone of *Amm. rostratus* and to make it the base of an English Cenomanian is no doubt a logical application of the classification which he had adopted for the beds in the East of France, but we think that arrangement was founded on a mistaken view of the chronological value of the typical Cenomanian of Maine and Normandy, a view which may be traced to the erroneous correlations of Prof. Hébert.

The next point for consideration is the junction of the zone of *Ammonites rostratus* with that of *Pecten asper*. This is of importance because some French geologists, notably Prof. de Lapparent, are prepared to throw the former into the Albien and to take the latter as commencing the Cenomanian. In the Isle of Wight, however, there is no break or great change of fauna at this horizon: the chert-beds are mere local deposits of organic silica (sponge-spicules), and *Pecten asper* occurs below as well as above them. No English geologist would think it natural to detach these beds from the Greensand and to group them with the Lower Chalk.

When we come to the junction of Chalk and Greensand, however, the case is different. Even here there is a passage and no sharp line of demarcation, but the passage is very rapid and it coincides with a great change in the fauna. Above the highest layer of cherts there are two beds which we should group with the Upper Greensand, and the uppermost of these passes into what we regard as the true Chloritic Marl or basement-bed of the Chalk. The

[1] 'Recherches sur le Terrain Crét. Sup. de l'Angleterre et de l'Irlande,' Lille, 1876.

following section was taken by one of us in 1880 from the slipped mass at Collins Point, near Ventnor :—

		Feet.
CHALK.	6. Chalk Marl with scattered glauconitic grains near the base, *Ammonites varians* and *Pecten Beaveri*	5
	5. Greenish-buff glauconitic marl full of fossils and phosphatic nodules, *Ammonites varians*, etc.	$3\frac{1}{2}$
UPPER	4. Compact, dark green, sandy marl, with quartz and glauconite, but few fossils or phosphatic nodules	$2\frac{1}{2}$
	3. A layer enclosing lumps of calcareous sandstone partially phosphatized, irregular pieces of dark phosphate and broken *Pecten asper*... .... about	$0\frac{1}{2}$
	2. Yellowish-green sand mottled with darker green ; yields *Pecten orbicularis*, *Ostrea vesiculosa*, and *Pecten asper*.	2
	1. Continuous layer of dark-grey cherty stone with compact green sand below, seen for	5

The material of 2 passes into that of 4 between the lumps of phosphatized stone in 3. At Niton 3 and 4 form a kind of boulder-bed full of such lumps, with phosphatized sponges, *Cardiaster fossarius*, *Pecten asper*, *Terebratella pectita*, and other fossils, but without any *Ammonites*. The Chloritic Marl (5), on the other hand, might be called a 'Cephalopoda Bed,' so abundant are ammonites of the species *varians*, *Coupei*, and *Mantelli*, with *Turrilites tuberculatus* and *Morrisii*. It is also characterized by the remarkable siliceous sponge *Stauronema Carteri* (Sollas), which has not yet been found below this horizon, nor far above it.

As one of us spent a week in 1880 for the purpose of examining these beds at the base of the Chalk, and afterwards engaged the services of Mr. M. Norman, of Ventnor, in collecting carefully from them, it seems desirable to give the list of fossils then obtained, in order to show the difference of the faunas. In this list the numbers above the columns indicate the beds as numbered in the section just described :—

	2.	3, 4.
PORIFERA (SPONGES).		
Halirrhoa agariciformis (phosphatized)..		
Plocoscyphia labrosa, Smith (phosphatiz		
Jerea Websteri		
Siphonia (phosphatized)		
Stauronema Carteri, Sollas		
ACTINOZOA.		
Micrabacia coronula, Goldf.		
ECHINODERMATA and ANNELIDA.		
fossarius, Benett ..		
idea subucula, Leske		
Hemiaster Morrisii, Forbes		
Holaster lævis, var. *carinatus* ..		
Serpula, sp.		
..., Sow.		

TABLE *continued.*

	2.	3, 4.	5.
BRACHIOPODA.			
Megerlia (Kingena) lima, Defr.	...	...	*
Terebratella pectita, Sow.	...	*	*
Terebratulina striata, Wahl.	...	...	*
Terebratula biplicata, Sow.	...	*	*
" *semiglobosa* (?), Sow.	...	...	*
Rhynchonella Grasiana, d'Orb.	...	...	*
" *Mantelliana*, Sow.	...	...	*
LAMELLIBRANCHIATA.			
Anomia, sp.	...	...	*
Ostrea vesicularis, Lam.	*	...	*
" *vesiculosa*, Sow.	*	*	*
" *carinata*, var. *frons*, Park.	...	...	*
Plicatula pectenoides, Sow.	*	*	*
" *inflata*, Sow.	*	...	*
Pecten asper, Lam.	*	*	...
" *Galliennii*, d'Orb.	*	...	...
" *orbicularis*, Sow.	*	*	*
" sp. nov. (allied to *fissicosta*, Eth.)	...	*	...
Janira quadricostata, Sow.	*	...	...
" *quinquecostata*, Sow.	...	*	*
Lima globosa, Sow.	*	...	*
Cardium hillanum (?), Sow.	...	...	*
Arca Mailleana, d'Orb.	...	...	*
" *obesa* (?), Pict. & Roux	...	...	*
Crassatella, sp. (casts)	...	...	*
Cardita tenuicosta (?), Sow.	...	?	*
Cyprina quadrata, d'Orb.	...	...	*
GASTEROPODA.			
Avellana cassis (?), d'Orb.	...	*	...
" sp.	...	...	*
Pleurotomaria Rhodani, d'Orb.	...	*	*
Solarium ornatum (?), Sow.	...	*	*
CEPHALOPODA.			
Ammonites Mantelli, Sow.	...	...	*
" *navicularis*, Mant.	...	...	*
" *varians*, Sow.	...	...	*
" " var. *Coupei*, Brong.	...	...	*
Turrilites Morrisii, Sharpe	...	...	*
" *tuberculatus*, Bosc	...	...	*
Hamites armatus (?), Sow.	...	...	*
Nautilus subradiatus, d'Orb.	...	...	*
" *expansus*, Sow.	...	...	*

This list appears to show that it is Bed 5 only which contains the characteristic fossils of the Chloritic Marl, and that in passing from 4 to 5 we cross the plane of division which separates two important faunas and two primary subdivisions or stages of the Upper Cretaceous Series. There are of course some species, particularly of

lamellibranchiata, which pass from one stage to the other, but the sudden incoming of a new and varied set of cephalopoda is sufficient to mark off one fauna from the other.

With respect to the Chalk Marl little need be said; it consists of alternating soft and hard beds, and the most abundant cephalopods are *Ammonites Mantelli*, *Amm. navicularis*, *Amm. varians*, *Turrilites costatus*, *T. Scheuchzerianus*, *T. tuberculatus*, *Baculites baculoides*, and *Scaphites æqualis*.

The higher part of the Lower Chalk is massive, white, and comparatively unfossiliferous, but at the top is a band of grey marl (zone of *Belemnitella plena*).

2. Dorset.

In Dorset both the stages above described—*i. e.* (1) the combined Gault and Greensand, (2) the Lower Chalk—are much thinner than in the Isle of Wight. The Gault-and-Greensand stage averages from 140 to 160 feet thick, but, instead of becoming steadily thinner to the west, the minimum thickness seems to be at Whitenose, near Weymouth, and in the extreme west of the county it swells out by the addition of sandy matter to about 200 feet. The Lower Chalk is about 140 feet thick near Swanage, but thins to less than 40 at Lulworth and Whitenose; whether it continues to thin towards the west is not known, as it is faulted out for a considerable distance and does not appear in the cliffs of West Dorset.

The most easterly cliff-section is at Ballard Hole or Punfield Cove near Swanage. This was well described in 1876[1] by Mr. H. G. Fordham, and, checking his account by Mr. Strahan's more recent measurements,[2] we have the following sequence:—

Section at Ballard Hole.

		Feet.
LOWER CHALK 143 feet.	Buff-coloured marl (zone of *Belemnitella plena*)	6
	Alternations of hard whitish chalk and layers of grey marl.	84
	Yellowish sandy chalk with phosphate-nodules	(?) 6
	Whiter chalk with a hard bed at the base full of *Brachiolites* (*Plocoscyphia*) and some phosphates	13
	Marly chalk, in alternating white and grey beds passing down into the next	30
	Glauconitic marl with fossils and phosphate-nodules, *Ammonites varians*, *Scaphites æqualis*, *Holaster subglobosus*, etc. (Chloritic Marl)	4
'UPPER GREENSAND,' 71 feet.	Nodular sandstone, consisting of irregular lumps of calcareous sandstone embedded in greenish sand, *Pecten asper*, *P. orbicularis*, *Ostrea vesiculosa*	5
	Greenish sand with occasional calcareous concretions	4
	Green sand without calcareous nodules, but with scattered fragments of brown phosphate, *Amm. rostratus*	17
	Two layers of greenish sandstone with dark green sand between them	5
	Bluish sandy clay with three stone-beds, one at the base; *Ammonites rostratus*, *Cucullæa glabra*, *Thetis Sowerbyi*, *Arca carinata*, and *Vermicularia concava*	40
GAULT.	Blue sandy clay passing down into stiffer clay	(?) 84

[1] Proc. Geol. Assoc. vol. iv. p. 506.

[2] Geol. Surv. Mem. 'Geology of the Isle of Wight,' 2nd ed. 1889, p. 66.

How much of the Lower Chalk should be regarded as belonging to the zone of *Ammonites varians* is doubtful, but it probably includes the sandy chalk with phosphates, and this would make a thickness of 53 feet.

It is especially noteworthy that there can be no doubt where the line between Chalk and Greensand should be drawn in this section. Here everyone has taken the same horizon, for there is no passage as in the Isle of Wight, but an abrupt change or break at the base of the Chloritic Marl, which rests on an irregular surface of the underlying sandstone as if a certain amount of current-erosion had taken place before its deposition.

The nodular sandstone is clearly the equivalent of the beds which contain similar concretions and the same fossils in the Isle of Wight, but the chert-beds are absent; as, however, they are only 13 feet thick at Compton Bay according to Mr. Strahan, it is not surprising to find them absent here. They are in fact a local and variable set of beds, and are absent over a large part of Dorset, though where present they always come in at the same horizon, and, as we shall presently see, they set in again a little farther west.

At Ballard Hole *Pecten asper* has only been found in the nodular sandstone, but as the sandy material of this bed passes down into the greensand below it is impossible to say how much should be included in this zone. There is in fact a complete passage down into sand that contains *Ammonites rostratus*.

As in the Isle of Wight, different observers have drawn the line between Greensand and Gault at different horizons. Mr. Fordham takes the Upper Greensand down to the lowest stone bed and thus gives a thickness of 71 feet to this division. Mr. Strahan draws the line higher up, assigning only 45 feet to the Greensand and 110 to the Gault. Neither have attempted a division into zones, and we do not yet know how much of this thickness should be assigned to the zone of *Ammonites rostratus*, and how much to those of *A. lautus* and *A. interruptus*; it is not probable, however, that the division into zones would coincide with either of the lines taken to separate Gault from Greensand.

The next fairly complete and accessible section is at Lulworth. The Lower Chalk was measured here by one of us in 1892, and found to be only 38 feet thick, a remarkable diminution of thickness. Dr. Barrois gave a detailed account of the Greensand portion in 1876,[1] and Mr. Meyer has kindly supplied us with a note on the beds at the junction of the Chalk and Greensand. Combining these sources of information, we have the following sequence:—

[1] 'Recherches sur le Terr. Crét. Supérieur, etc.,' p. 89.

Section at Lulworth Cove.

		Feet.
LOWER CHALK.	Soft, greenish, buff-coloured marl (zone of *Bel. plena*)	6
	White chalk in regular beds, divided by thin seams of marl	16
	Soft, whitish chalk, blocky and not bedded, enclosing siliceous nodules or flints	12
	Glauconitic chalk with phosphatic nodules	4
ZONE OF PECTEN ASPER.	Hard, nodular, calcareous sandstone (1 foot), passing down into similar but more sandy and evenly-bedded rock; many fossils	8
	Sand with two or more layers of chert	5
	Marly greensand with small phosphatic nodules, *Pecten asper* and many other fossils	7
ZONE OF AM. ROSTRATUS.	Greensand with beds of calcareous sandstone	14
	Greenish sand with an oyster-bed 10 feet down and a layer of fossiliferous concretions at the base	16
	Grey micaceous sands with two layers of grey sandstone: *Vermicularia concava*	44
GAULT.	Black sandy clay, seen for	15
	Dark blue clays	(?) 45

In this section a noteworthy point is the occurrence of flints in the Lower Chalk. These flints do not disengage themselves like ordinary chalk-flints, but have more resemblance to the siliceous concretions which occur in the Lower Chalk of Wiltshire.[1] They are enveloped in a thick coat of white siliceous chalk, which often seems to pass inward into grey or black flint and outward into the pure chalk. The amount of completely silicified matter or flint varies greatly, being sometimes a fairly large mass and sometimes a mere nucleus, and some concretions have none at all.

These flints also occur at Whitenose and in many other parts of West Dorset, and we call especial attention to them, both because the idea that real flints do not occur in Lower Chalk is still current in some quarters, and because siliceous concretions of the nature of cherts occur in the Cenomanian of Normandy.

Lithologically there is nothing at Lulworth which can be called Chalk Marl, but, as Dr. Barrois records *Ammonites varians* and *Rhynchonella Mantelliana* from these beds at Ringstead Bay, they may represent part of the Chalk Marl. Whether the basement-bed with its phosphate-nodules represents the true Chloritic Marl or *Stauronema*-bed we think very doubtful; more probably it should be regarded as a condensed equivalent of the lower part of the Chalk Marl.

The junction of Chalk and Greensand is even more abrupt and well marked than at Punfield, the base of the glauconitic chalk resting on an uneven and current-washed surface of the underlying sandstone. The uppermost foot of this sandstone, moreover, is rough, nodular, and more calcified than the part below, as if it had been exposed to some alterative influences before the deposition of the overlying chalk.

The zone of *Pecten asper* is well marked; the chert-beds are coming in again, and, with a marly greensand below, in which Dr. Barrois also found *P. asper*, give the zone a thickness of 20 feet.

[1] See Quart. Journ. Geol. Soc. vol. xlv. (1889) p. 403.

But, with the exception of a rare specimen of *Ammonites Mantelli*, the Chalk Marl cephalopoda do not descend below the base of the Chalk.

The section at Whitenose appears to be similar to that at Lulworth, but thence westward there is no cliff-section of Cretaceous rocks for a long distance. Inland exposures as far west as Bridport show a sequence like that of Lulworth; the Lower Chalk is as thick or thicker, and has the same fossiliferous nodule-bed at the base.

Between this district and Pinhay, near Lyme Regis, a distance of about 14 miles, the whole of the Chalk has been removed by Tertiary erosion, but sections of the Gault and Greensand show that this lower stage attained a thickness of nearly 200 feet in the extreme east of Dorset.

3. Devon.

We now come to Devon, where the Greensand attains a great thickness, and the representative of the Lower Chalk differs as much from the ordinary English type as that does from the French Cenomanian. We have seen that in West Dorset the Lower Chalk is still chalk with a definite basal nodule-bed. Where the Chalk comes in again below Pinhay, west of Lyme, the succession at the junction of Chalk and Upper Greensand is as follows:—

Section below Pinhay.

		Feet.	In.
T.	7. Hard, rough, nodular chalk, with *Inoceramus mytiloides*, *Cardiaster pygmæus*, and *Cidaris hirudo*	1	9
	6. Hard glauconitic chalk, with *Inoceramus mytiloides* and *Cidaris hirudo*	1	9
	5. Softer chalk, full of quartz and glauconite, with many phosphate-nodules and derived fossils at the base	0	9
M.	4. Hard, rough, quartziferous limestone with large green-coated lumps, fossils not abundant. About	1	0
	3. Hard, compact, shelly limestone, fine-grained above, but coarse and quartzose at the base, which rests on an eroded surface of the bed below	1	6
G.	2. Calcareous sandstone with few fossils, indurated and calcified in the upper part, softer below	8	0
	1. Chert-beds, fine sandstone with irregular concretions of chert, seen for	22	0

These beds fall into three natural groups as bracketed, which we may for the present call G, M, T.

Group G is clearly the higher part of the Upper Greensand, and the calcareous sandstone occupies the place of the similar bed in Dorset. *Pecten asper* has not been found in it, but the fossils which do occur are those of its Dorset equivalent.

Group M.—All the beds above the calcareous sandstone are very variable in thickness. Nos. 3 and 4 are in one place less than a foot thick, but expand in a short distance to more than 3 feet. The lower bed contains a mixture of fossils which are elsewhere characteristic of separate zones; some of the so-called 'zone of

Pecten asper,' such as *P. asper* itself, *P. Galliennei*, and *carinatus*; some of the Lower Chalk, such as *Ammonites varians*, *A. Mantelli*, and *Scaphites æqualis*; near the base, too, a peculiar large coralloid polyzoan (*Ceriopora ramulosa*) is not uncommon. The upper bed has fewer fossils, but the same ammonites occur with, occasionally, *Scaphites æqualis*. These two beds are well marked off from those above and below, and may be called the zone of *Ammonites Mantelli*.

The upper surface of No. 4 is always a layer of brown phosphatic nodules; these are now 'welded' on to this bed, but the interstices between them are filled with the material of the overlying bed. This bed, No. 5, is full of large grains of quartz and glauconite, but has a chalky matrix, and is much more friable than the bed below. Setting aside the derived phosphatic fossils, of which there are many, the commonest fossil in bed 5 is *Rhynchonella Wiestii*, a species which is closely allied to *Rh. Cuvieri*. With it are found *Belemnitella plena* and *Discoidea cylindrica*, so that, looking to the fossils, the bed would seem to be the equivalent of the *Belemnitella*-marls of Dorset and other counties. Physically, however, it is the base of the Middle Chalk or Turonian, for it passes up into the hard glauconitic chalk which contains only Turonian species.

As to the succeeding yellowish nodular chalk, there can be no doubt regarding its age; it has some resemblance to the Melbourn Rock, and may be regarded as its equivalent. We think, therefore, that the Middle Chalk has here a basement-bed of gritty glauconitic chalk, containing derived fossils, which bears the same relation to the Melbourn Rock as the basement-bed in Dorset does to the Chalk Marl.

If the above inferences are correct, the only beds which can be regarded as the equivalents of the Lower Chalk in this section are Nos. 3 and 4. Mr. C. J. A. Meyer saw these beds in 1895, and at once recognized No. 3 as a union of the 10 and 11 of his Beer Head section,[1] No. 4 as his bed 12, and the overlying beds as his 13 and 14. He is now, however, prepared to agree with our correlation of these beds.

Group M, the zone of *Ammonites Mantelli*, can be followed above the landslips of the coast-line between Lyme Regis and Axmouth running out near the top of Haven Hill, above the mouth of the Axe.

West of Seaton the Greensand and Chalk are brought in again by a fault and a syncline, an excellent section being exposed along the face of Whitecliff. The details of this will be given in the Survey Memoir, and it is only necessary to notice here that the glauconitic chalk (No. 5) is absent, the hard nodular yellowish chalk (No. 6) resting directly on the zone of *A. Mantelli*. The latter, moreover, forms one massive bed from 2 to 3 feet thick, though careful examination shows that beds 3 and 4 enter into its composition.

The Upper Greensand is about 160 feet thick, including a sandy

[1] Quart. Journ. Geol. Soc. vol. xxx. (1874) p. 369.

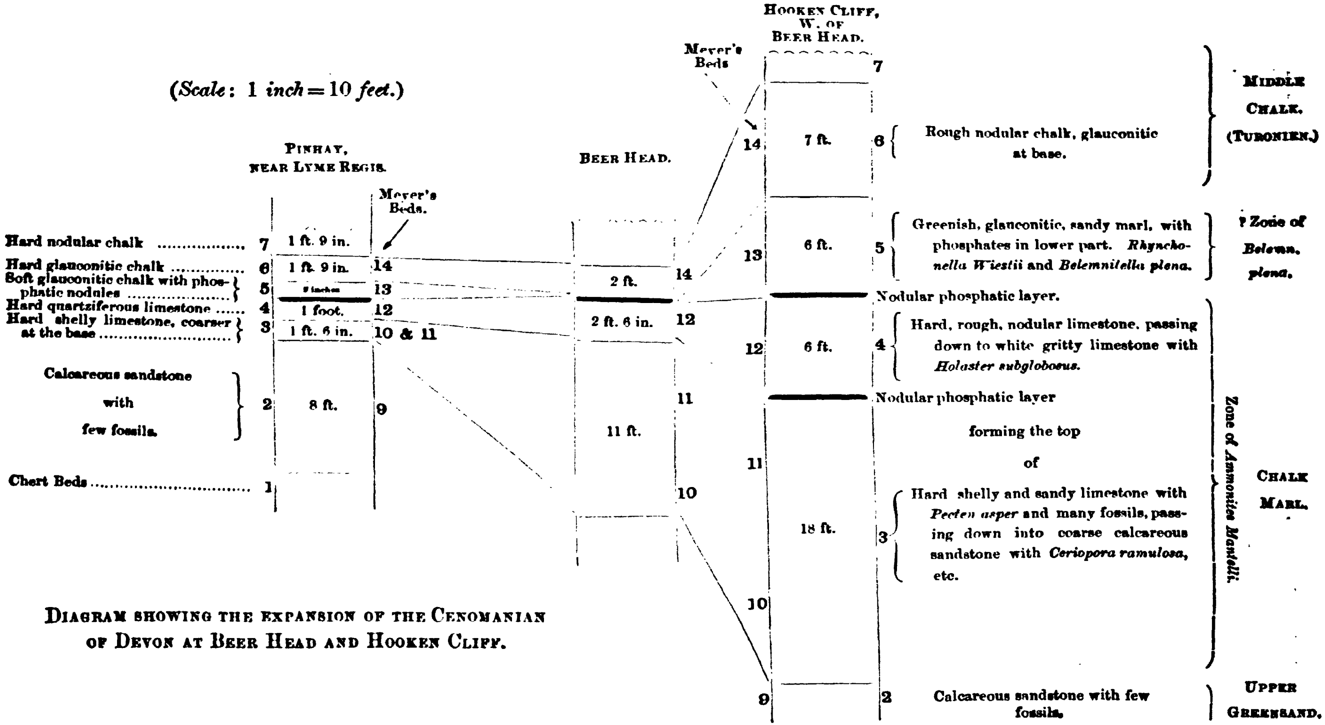


DIAGRAM SHOWING THE EXPANSION OF THE CENOMANIAN OF DEVON AT BEER HEAD AND HOOKEN CLIFF.

representative of the Gault. The following is a condensed view of the beds which compose this stage in Whitecliff:—

	Feet.
Hard calcareous sandstone, few fossils	8
Yellowish sand and sandstone, with numerous layers of chert ...	56
Dark green sand and hard glauconitic stone............................	4
Green, grey, and purple sand, with layers and concretions of hard calcareous sandstone	70
Dark green argillaceous sand seen for	15
	153

The beds at the junction of the Chalk and Greensand may be followed along the foot of the magnificent range of cliffs which extends from Beer Harbour to Beer Head, and near that headland the zone of *Ammonites Mantelli* can be seen to thicken out rapidly, the thickening being chiefly produced by the addition of material to its lower bed, till at Beer Head the whole is about 14 feet thick, and is very clearly divisible into two parts or beds. The upper bed, 2½ feet thick, is a rough quartziferous limestone with layers of green-coated nodules, and in it *Holaster subglobosus* is common; the lower bed is in its higher part a hard shelly and gritty limestone, with *Pecten subinterstriatus*, *P. asper*, *Ammonites Mantelli*, *Rhynchonella dimidiata*, *Pseudodiadema variolare*, and many other fossils; in this higher part the grains of quartz and glauconite are small, but in the lower 5 feet the former are large and the rock becomes a rough and coarse calcareous grit, in which the most abundant fossil is the large, branching, coral-like *Ceriopora ramulosa*. The plane of division between its base and the Upper Greensand below is well marked.

These two beds include Mr. Meyer's beds 10, 11, 12, but there is no clear representative of his 13, the glauconitic chalk or marly greensand, though there are patches and nests of such sand at the base of the overlying chalky limestone (Turonian).

We now come to the place where these beds attain their greatest development; this is in the great Southern-down landslip, and in the cliff from which it was detached, known as Hooken Cliff. Here the zone of *Ammonites Mantelli* is 24 feet thick, and the succession is as follows:—

		Feet.
Turonian.	6. Hard, rough, nodular chalk, glauconitic at base ...	7
	5. Greenish, sandy, glauconitic marl, with a few brown phosphate-nodules in the lower part; *Rhynchonella Wirstii*, *Belemnitella plena*, etc.	6
Zone of Amm. Mantelli.	4. Layer of brownish green-coated nodules at top of hard, rough, nodular limestone, passing down into white gritty limestone with *Holaster* [illegible] ...	6
	3. Hard, rough, nodular layer with phosphatic matter, passing down into hard shelly and sandy [illegible]stone with *Pecten asper* and many other fossils; the quartz-grains getting larger in the lower part, and the rock passing into a coarse calcareous sandstone with 'corals'	18
Upper Greensand.	2. Even-grained calcareous sandstone with few or no fossils	?

The numbers above given correspond with those of the Pinhay section, and the whole is, in fact, an expanded counterpart of that section (see p. 112). The upper surfaces both of 3 and 4 are more clearly marked, while the glauconitic chalk (No. 5), as near Lyme Regis, passes up into the hard rough nodular chalk above, which contains *Echinoconus subrotundus*. It is a remarkable instance of the rapid changes which take place in these beds that this No. 5 should be here 6 feet thick, though at Beer Head, only 400 yards away, it is represented merely by small nests of sand.

We are able to state that, as a result of revisiting this section in company with one of us, Mr. Meyer no longer maintains his correlation of his beds 10, 11, 12 (our zone of *Amm. Mantelli*) with the Warminster Greensand or with the Chloritic Marl, nor of his 13 and 14 with the Chalk Marl. He had in 1874 perceived the clear lines of demarcation which exist at the top of his No. 9 and at the top of No. 12, and he now agrees with us that the beds so limited must represent either the whole or a part of the Lower Chalk.

It is quite possible that only a part of the Lower Chalk is here represented; for, whether we take bed 5 of our section to be the zone of *Belemnitella plena* or the base of the Middle Chalk, there is clearly a break between it and the bed below, so that we may assume that there is nothing to represent that part of the Lower Chalk which lies between the zone of *Ammonites varians* and that of *Belemnitella plena*.

Whether material was deposited here and afterwards washed away by current-erosion, or whether no deposition took place in the interval, it is at present impossible to say, but for our present purpose it is sufficient that there is here an arenaceous representative of the Chalk Marl containing most of the characteristic fossils of that marl mixed with a number of other species which are evidently shallow-water forms, and these species are, as we shall see, almost all found in the Cenomanian of the Sarthe.

Confirmation of our reference of these beds to the lower part of the Lower Chalk is found in the neighbourhood of Chard and Chardstock, the latter place being only 9 miles north of Lyme Regis. The succession here has been accurately given by Mr. H. B. Woodward,[1] and so far as the Upper Greensand is concerned it resembles that of the coast-section. The upper surface of the Greensand is a well-marked plane, and upon it rests a hard quartziferous and glauconitic chalk crowded with fossils: this passes up into softer glauconitic chalk, which rapidly graduates into chalk with few fossils. Of this white chalk there is probably 30 or 40 feet, and there is some thickness of yellowish marl above it, all belonging to the Lower Chalk.

The basement of this Lower Chalk has been called Chloritic Marl, and it has long been celebrated for the abundance and good preservation of its fossils. The assemblage, however, is rather that of the whole Chalk Marl than that of the Chloritic Marl of the Isle of Wight, and it also includes some of the rare and peculiar species

[1] 'Geology of England and Wales,' 2nd ed. 1887, p. 392.

ions.

...th.	Feet.	Feet.	Beer Head.	
[redacted]	6	14	Limestones.	Cenomanian.
...halk.	16			
...h flints	1			
[redacted]	4			
...Beds.	20	64	Chert Beds.	'Greensand.'
...ands ...lstones	74	58	Grey and Buff Sands.	
...Clay	60	35	Argillaceous Sands.	

which occur in the quartziferous limestones of the coast. It is especially rich in ammonites, and nearly all the species occurring at Chard are found also in our coast-zone of *Ammonites Mantelli*, as will be seen from the list given on p. 159.

The relative thickness of the beds in the principal sections above described is shown in the accompanying 'Tabular View.'

III. A Study of the Cliffs between Cape La Hève and Brunval.

The bold and almost unbroken line of cliffs which form the French coast from Cape d'Antifer to Cape La Hève present a section of the Cretaceous series from the higher zones of the Upper Chalk seen at the first-named promontory to the yellow sands which form the basement-bed, and which can be seen overlying the Jurassic rocks at Cape La Hève.

The general trend of these cliffs is about N.N.E. and S.S.W., but at the mouth of the Seine, after passing the lighthouses at Cape La Hève, the cliff turns to the south, making an obtuse angle to the general coast-line.

Between Cape La Hève and St. Jouin, a distance of some 11 miles, the strata are nearly horizontal, and the series seen are the beds from the base of the Cretaceous series to an horizon equivalent to our Grey Chalk; but at St. Jouin the beds dip gradually to the eastward, and the whole series is brought down to sea-level.

The section has been well studied by many French geologists, notably by MM. Lesueur,[1] le Vicomte d'Archiac,[2] Hebert,[3] de Lapparent,[4] and Lennier,[5] but even their descriptions do not furnish a complete account of the whole section, nor do they give full lists of the fossils found in the various beds.

Moreover, since De la Beche's visit in 1821,[6] and Mr. Pratt's[7] notice in 1837, no English geologist seems to have studied this fine section. Those who have described English Cretaceous fossils seem to have taken it for granted that the Cenomanian of Normandy included representatives of both our Upper Greensand and Lower Chalk; but, so far as we can ascertain, no one has hitherto attempted to ascertain how much of this Cenomanian would be regarded as the equivalent of the Lower Chalk. This has been our endeavour, but before entering into details we give the general succession of the series below the Turonian, as seen in the cliffs. This is as follows in descending order, the grouping being that of M. Lennier and Prof. de Lapparent:—

[1] 'Vues et Coupes des Environs du Havre.' Paris, 1843.

[2] 'Études sur la Formation Crétacée,' Mém. Soc. Géol. France, ser. 2, vol. ii. p. 95.

[3] Bull. Soc. Géol. France, ser. 2, vol. xxix. (1872), p. 446; *ibid.* ser. 3, vol. iii. (1875) p. 512.

[4] 'Traité de Géologie,' 2nd ed. 1885, p. 1074.

[5] Bull. Soc. Géol. Normandie, vol. vi. p. 380, and vol. ix. p. 56 (1880 & 1884).

[6] Trans. Geol. Soc. ser. 2, vol. i. pt. i. (1822) p. 73.

[7] Proc. Geol. Soc. vol. ii. p. 546.

		Feet.
Cenomanian.	8. Firm greyish-white chalk, with layers of chert-nodules	30 to 40
	7. Greyish glauconitic chalk, with cherts and hard calcareous concretions and many brown phosphatic nodules in the lower part	10 to 11
	6. Greyish-white or yellowish chalk, with many layers of greyish-black chert. A bed of hard, grey, shelly, glauconitic chalk occurs in the middle at St. Jouin, but dies out westward	70 to 80
Gaize and Gault.	5. Bluish-grey, sandy, and very glauconitic marl with many black phosphatic nodules	3½ to 6
	4. Bluish-grey, sandy, glauconitic marl with layers of hard siliceous concretions	23 to 26
	3. Dark grey, nearly black, sandy, glauconitic clay with phosphatic nodules at the base	10 to 11
? Aptien.	2. Coarse, brown, pebbly sandstone	15 to 16
	1. Fine, yellow, micaceous sand	70

Upper Neocomian Sands—Aptien.

The sands which form the base of the Cretaceous series at La Hève are yellowish, fine, and micaceous, easily dug with the fingers, and veined or streaked with red-brown iron oxide, which frequently cements the grains together in thin platy pieces. Near the top are some concretionary masses of ironstone.

Immediately overlying these sands, and sharply divided from them, is a bed of brown, pebbly, sandy grit, closely resembling unconsolidated Carstone. Many fragments of fossil wood occur in it; other fossil remains are rare, but M. Lennier has obtained *Ostrea aquila* and *Ammonites Milletianus*.[1] Like all the beds of the lower part of the Cretaceous series, it thins to the southward; its thickness nearly a mile east of Cape La Hève is 16 feet, while at Ste. Adresse, south-west of the headland, its thickness has diminished to 11 feet.

The sequence of these beds has been differently classified by French geologists at different times.

The yellow micaceous sands and the brown pebble-bed above them, Nos. 1 and 2 in our section, were first regarded by Prof. Hébert in 1872[2] as 'Néocomien supérieur,' which was his name for the Aptien of d'Orbigny. In 1875, however, he was inclined to range these sands with the Gault, because he had found fragments of *Ammonites Milletianus* in the sands near Octeville, and because M. Lennier had obtained fossils identified as *Ammonites Deluci*, *Trigonia Fittoni*, and *Nautilus Bouchardianus* from these sands at Havre. The two beds are so exactly the counterpart of those at the summit of the Lower Greensand in the Isle of Wight, and described in the Survey Memoir under the name of 'Sand Rock Series' and 'Carstone,' that we cannot help thinking that Prof. Hébert's first opinion was the correct one. Certainly it would be strange for the species above mentioned to occur in an Aptien sand, but M. Lennier informs us that he is by no means certain of the identification of these fossils.

[1] Recorded by Prof. Hébert, Bull. Soc. Géol. France, ser. 3, vol. iii. (1875) p. 516.

[2] *Op. cit.* ser. 2, vol. xxix. p. 449.

The Gault and Upper Greensand—The Albien of M. de Lapparent.

Above the coarse pebbly grit comes a dark, sandy, glauconitic clay, almost black when wet, which passes up into a sandy and glauconitic marl. This is the equivalent of our Gault and Greensand, the Gault and Gaize of French geologists; there is no plane of division between them, the one gradually passing up into the other.

The lower part of this division can be conveniently seen near Ste. Adresse, ½ mile south-west of the lighthouses, where the following section was taken, in descending order:—

GAULT.	Dark bluish-grey, sandy, micaceous, and glauconitic clay, seen for	7 feet.
	Dark bluish-grey (almost black), sandy, and very glauconitic clay, containing a few light-coloured phosphates (dark internally)	4 feet.
	Bed of phosphatic nodules, contained in a mixture of the underlying coarse sand and the glauconitic sandy clay above	6 inches.
APTIEN.	Coarse, brown, sandy grit, containing pebbles as large as a bean	3 feet.
	Coarse, brown, sandy grit	8 feet.
	Soft greyish-yellow sand was seen below this; the junction-bed, however, was not attainable	15 18 feet.

The bed of light-coloured phosphate-nodules intermingled with the bed below, the nodules often including small quartz and lydian-stone pebbles.

The micaceous clay of the Gault passes up into a sandy, glauconitic, micaceous, and slightly calcareous marl containing small dogger-like concretions, and as one follows it upward these concretions increase in importance and number, and finally divide the deposit into courses. At the top of the division the doggers give place to definite beds in which silica seems to saturate the deposit, forming hard courses, which alternate with courses of softer marl.

The following is a detailed section through the Gaize and Gault at a point nearly 1 mile east of the lighthouses on Cape La Hève:—

		Feet.	Inches.
	Chloritic Marl (see p. 119)	6	0
GAIZE or UPPER GREENSAND.	Alternating beds of blue-grey marl and beds of hard siliceous stone	3	6
	Dark blue-grey, sandy, glauconitic marl, containing doggers of hard siliceous stone, arranged more or less in la[illegible]s	7	0
	A double line of doggers, separated by blue-grey, sandy marl	1	9
	Blue-grey, softish, sandy marl	1	3
	Dark blue-grey marl, with a line of large and well-separated doggers	1	9
	Dark blue-grey marl, with small scattered doggers, arranged more or less in lines	11	0
GAULT.	Very dark, almost black, marly, glauconitic clay; a layer of phosphatic nodules at the base	10	0
APTIEN.	Coarse pebbly brown sand	16	0
	Yellow micaceous sand	70	0

Like the pebbly sand, these beds diminish westward; for just south of the lighthouses the thickness of Gault and Gaize is 28 feet. M. Lennier gives the thickness of the Gault at Cauville, some 6 or 7 miles north-east of Cape La Hève, as 22–23 feet, and he divides it into three beds.[1] Here therefore the combined thickness of Gault and Gaize is probably about 50 feet.

Prof. Hébert[2] was of opinion that no actual representative of the Gault occurs at La Hève. He refers to its existence at Cauville, and states that common Gault fossils were there abundant and well-preserved. He also admits its occurrence near Octeville, where 'the bed of conglomerate is covered by a blue clay without glauconite, but containing many small pebbles of quartz and septaria, with Gault fossils.'

'At Cape La Hève,' he says, 'this bed is only represented by a layer of septaria, of pebbles, of vegetable fragments, or of fossils of the Gault, washed by the waters which brought the glauconite, and *remaniés* in the midst, and especially at the bottom of this deposit, in contact with the conglomerate.' This appears to be a description of the basal nodule-bed; these 'septaria' are doubtless what we have called phosphate-nodules.

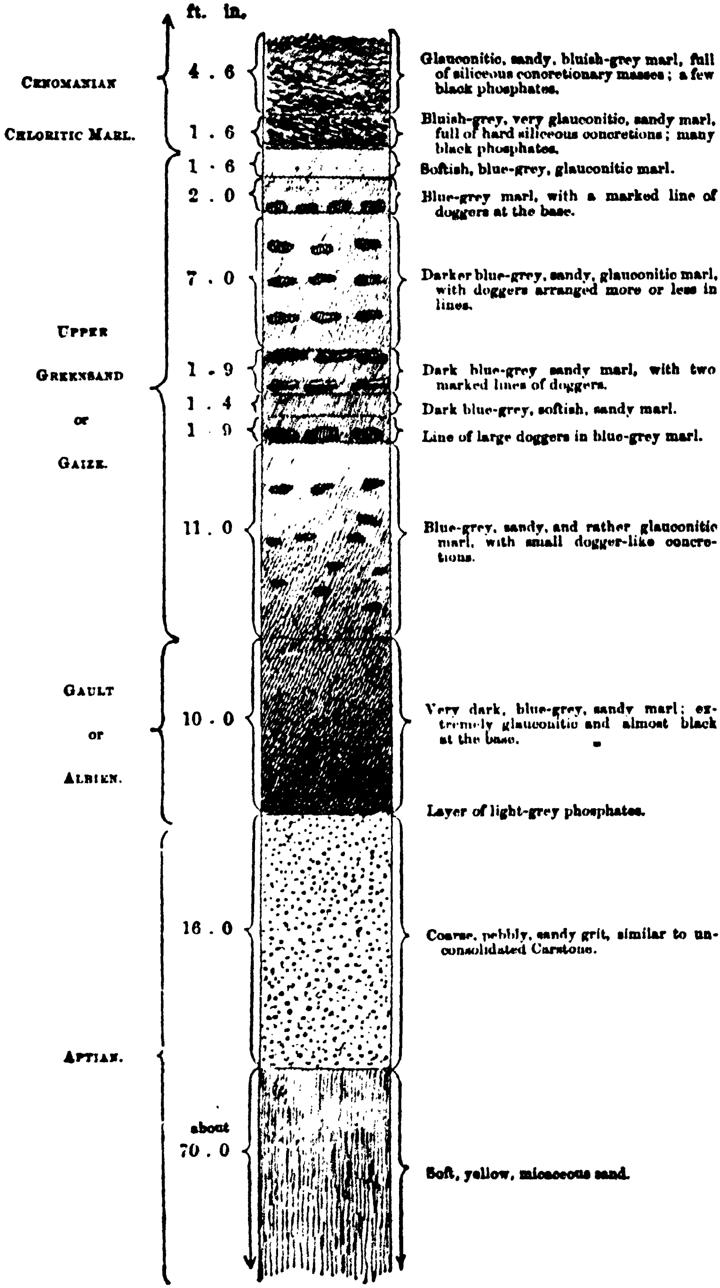
He continues as follows:—'Je range dans cette dernière assise (Craie glauconieuse) les argiles noirâtres, très glauconieuses, avec lits siliceux intercalés, qui, au Cap La Hève, reposent immédiatement sur le poudingue à *Ostrea aquila*;' and he gives the thickness of these beds as from 16 to 20 metres (*i.e.*, 52 to 66 feet). This great thickness suggests to us that Prof. Hébert may have included in this division of the Craie glauconieuse all the beds which have a blue-grey colour, for our measurements make them 52 to 55 feet. This view receives some confirmation from his further remarks, which are:—'It is true that there occur in this series a certain number of Gault species, whose existence I do not deny, but these beds also yield a good number of the more characteristic species of the Craie glauconieuse: among Echinoderms, *Epiaster crassissimus*, *Epiaster distinctus*, *Holaster suborbicularis*, *Cardiaster bicarinatus*, which abound, the last especially, in one of the siliceous beds; among the Acephala, *Panopæa mandibula*, *Ostrea conica*, etc. It is this lower series that I have designated by the names of the zone of *Holaster suborbicularis* and *Ammonites inflatus*.'

Of the echinodermata mentioned above we found only *Epiaster crassissimus*, and that is common above bed 5. We did not find any below, and even if they did occur we cannot regard that fact as very significant. There is no doubt that our bed 4 belongs to the zone of *Ammonites inflatus*, but both M. Lennier and Prof. de Lapparent exclude that zone from the Cenomanian; and we are entirely of their opinion on this point.

Being familiar with the lithological change which our Gault exhibits as it is traced westward, we see no reason for considering the Gault to be absent because the clay which occupies its

[1] Bull. Soc. Géol. Norm. vol. vi. (1880) p. 358.
[2] Bull. Soc. Géol. France, sér. 3, vol. iii. (1875) p. 516.

(*Taken nearly a mile east of the Lighthouses.—Scale*: 1 *inch* = 10 *feet.*)



place is full of glauconite. The lower 10 feet of this series is a material which resembles the Gault at Black Ven, near Lyme Regis; it is doubtless from this 10 feet and from the overlying 23 feet of less dark and slightly micaceous marl that the Gault species have been obtained. We have, indeed, obtained *Ammonites rostratus* (var.) and *Ammonites auritus* from the upper beds in a large fallen mass at Cape La Hève. These higher beds we regard as the Gaize or zone of *Ammonites inflatus*, the representative of the Cowstone beds at Black Ven, of the Malmstone, and of the grey micaceous sands which form the lower part of the Upper Greensand in Wiltshire and North Dorset.

The Gault is poor in fossils, but we have found *Pecten orbicularis* and *Exogyra conica* just above the phosphates near Cape La Hève. The following is a list of the fossils which we found in the upper beds (Gaize) at Cape La Hève and St. Jouin:—*Holaster lævis*, *Ostrea lateralis*, *O. vesicularis*, *Avicula* (near to *Rauliniana*, d'Orb.), *Lucina Dupiniana*, *Thetis Sowerbyi*, *Avellana incrassata* (?), *Gibbula levistriata* (?), *Ammonites auritus* (typical form), *A. Raulinianus* (?) small, and *A. rostratus* (a form resembling one common in the Gaize of Devizes). In the very highest layer, just below the Chloritic Marl, *Rhynchonella convexa* and *Rh. Schloenbachi* occur.

The section on the preceding page shows the succession of the beds below the Cenomanian which form the headland of Cape La Hève.

The Cenomanian (Bed 5).

We dissent entirely from Prof. Hébert's classification of beds 4 and 5, and agree with that of M. Lennier and Prof. de Lapparent, for there can be no question as to the exact horizon where the distinctive Cenomanian fauna sets in.

M. Lennier gives the total thickness of this division at Cape La Hève as 32·75 metres (108 feet). Our measurements give only about 90 feet from the base upwards, and although more chalk is to be seen above this, it is not well shown or easily examined. With regard to detailed measurements, our own do not quite tally with those of M. Lennier, but we differ only in such manner as may occur between persons who measure a somewhat variable set of beds at different times and at different points in a long cliff-section.

M. Lennier[1] has given a complete section of the Cenomanian of Cape La Hève; he divides it into 11 beds, 10 of which are seen at La Hève, the uppermost only coming in between Brunval and St. Jouin. He describes the basement-bed as a soft sandy glauconite, sometimes containing hard blocks ('roches'), with nodules of phosphate of lime perforated by lithodomous mollusca, from 1 to 2 metres thick. This bed is very rich in fossils, the commonest being *Ammonites Mantelli*, *A. varians*, *Pleurotomaria perspectiva*, *Pl. Mailleana*, *Ostrea conica*, *O. serrata*, *O. Lesueuri*, *Spondylus striatus*, *Rhynchonella compressa*, etc.

From this description there can be no doubt that he takes the

[1] Bull. Soc. Géol. de Normandie, vol. vi. (1880) p. 380.

base of the Cenomanian at the bed of sandy glauconitic marl, which contains black phosphates (see p. 119), and in this we entirely agree. There is here a well-marked plane of division, for the phosphate-bed is separated from the marl below by a seam of sand, full of glauconitic grains, a rich brown in the centre, from 2 to 3 inches thick. This brown sand was noticed in all the sections between Cape La Hève and St. Jouin, except at one place, about a mile east of the lighthouses. The soft marl forming the bed itself is full of glauconite, the grains being large as well as abundant; small quartz-pebbles are not uncommon, and the black phosphatic nodules are not unlike those of the Cambridge Greensand; indeed, an analysis by Berthier quoted by M. Lennier shows that they contain 57 per cent. of phosphate of lime. The following is a list of the fossils collected by one of us from this nodule-bed; a few marked L are given on the authority of M. Lennier, and we are indebted to Dr. G. J. Hinde, F.G.S., for naming the sponges and polyzoa:—

PORIFERA.

Trematocystia siphonioides, Mich.
—— *d'Orbignyi*, Hinde.
Corynella rugosa, Hinde.
——, sp.
Elasmostoma consobrinum, d'Orb.
—— *plicatum*, Hinde.
Jerea, sp. (= *Siphonia*).
Pachypoterion compactum, Hinde.
Stauronema Carteri, Sollas.
Plocoscyphia (?) fragments.

HYDROZOA.

Porosphæra urceolata, Phil.

ANNELIDA.

Ditrupa difformis, Lam.
Galeolaria plexus, Sow.

ECHINODERMATA.

Cidaris vesiculosa, Goldf.
——, sp.
Discoidea subucula, Klein.
Goniophorus, sp.
Salenia, sp.
Pseudodiadema ornatum, Goldf.
—— *Benettiæ*, Forbes.
—— *variolare*, Brongn.
L *Holaster subglobosus*, Leske.

POLYZOA.

Ceriopora (*Ceriocava*) *mammillaris*, d'Orb.
Diastopora, sp.
——, sp.
Alecto. sp.
Melicertes compressa, d'Orb.
Sparsicava irregularis, d'Orb.
Radiopora (*Domopora*) *tuberculata*, d'Orb.

POLYZOA (continued).

Radiopora ornata, d'Orb.
Micropora, three species.

BRACHIOPODA.

Rhynchonella dimidiata, Sow.
—— *convexa*, Sow.
—— *Grasiana*, d'Orb.
Megerlia lima, Defr.
L *Terebratula biplicata*, Sow.
Terebratella pectita, Sow.
L *Terebrirostra lyra*, Sow.

LAMELLIBRANCHIATA.

Exogyra conica, Sow.
—— *Rauliniana*, d'Orb.
Ostrea canaliculata, Sow.
—— *Lesueuri*, Sow.
—— *carinata*, Sow.
Pecten asper, Sow.
—— *Dutempliana*, d'Orb.
Neithea quadricostata, Sow.
Spondylus striatus, Sow.
Trigonia spinosa, Ag. (non Park).
Cyprina, sp.

GASTEROPODA.

Avellana cassis (?), d'Orb.
Natica (like *gaultina*).
L *Pleurotomaria Mailleana*, d'Orb.
—— *perspectiva*, Sow.
Turbonilea, sp.

CEPHALOPODA.

Ammonites Mantelli, Sow.
—— *navicularis*, Mont.
—— *varians*, Sow.
Scaphites æqualis (a fragment).
L *Nautilus subradiatus*, d'Orb.
Turrilites, sp.

It will be seen that the contrast between this fauna and that of the beds below is very great. It is the incoming of an entirely new set of fossils, and the presence of *Stauronema Carteri* is a strong confirmation of the view which at once impressed itself upon us that the bed corresponds to the Chloritic Marl of the Isle of Wight. Almost all the brachiopoda and mollusca occur in our Chloritic Marl, though most of them occur also in the highest bed of the Upper Greensand near Warminster, which is part of the so-called 'zone of *Pecten asper*.' The relations of this zone in England to the French Cenomanian will be discussed in the sequel.

What we desire to point out in the present connexion is that in the cliffs near Havre there can be no question where the Cenomanian fauna commences: that it comes in suddenly with a bed which resembles our Chloritic Marl, both in its mineral composition and in its fossil contents, and in its included phosphatic nodules. Above this bed there is no break whatever, and, though the material of the overlying beds is different from that of our Chalk Marl, these beds pass up gradually into a true chalk near the top of the formation.

Bed 6.

At and near Cape La Hève the phosphate-bed is succeeded by beds of soft marly and glauconitic chalk, divided by layers of a peculiar kind of siliceous stone. Examination of this stone proves it to be permeated and indurated with colloid silica, the condition of the material being in every stage from merely hardened chalk to a blue-grey siliceous mass, like the immature chert occurring in the Chalk Marl of Wiltshire, and described by us,[1] while here and there it is concentrated into nuclei of pure crystalline silica. The result at this horizon is not definite chert or flint, but ramifying masses of siliceous material, passing in places to clear black or grey-coloured chert or flint, without any definite rind.

These beds are discontinuous, and there is a good deal of variation in the succession of chalk and chert, even in sections a short distance apart.

Between these hard beds the chalk is soft and marly, sometimes firm, but it always contains much glauconite in grains of rather small size compared with those of the Chloritic Marl. The hard beds gradually become less marked, and separated nodules or beds of chert begin to appear.

The incoming of the cherts at La Hève is marked by five courses of exceptionally massive character, and these form a striking feature in the cliff-face. A little east of the lighthouses the lowest line is 34 feet above the base of the Chloritic Marl, but nearer Havre it is only 27 feet 6 inches above it.

Above and between these cherts to the top of Bed 6 the chalk is of a pale yellowish-white colour, firm in character, and rather

[1] Quart. Journ. Geol. Soc. vol. xlv. (1889) p. 403.

rough or gritty to the touch, and it contains less glauconite than that below.

Grey or black cherts in separated nodules continue to occur either scattered through the chalk or in lines at irregular intervals.

The bluish colour, probably due to argillaceous matter deposited with the chalk, gives place very irregularly to the yellowish-grey which is the characteristic tint of the French Cenomanian. Sometimes it extends up for 12 or 14 feet above the basement-bed, sometimes only 3 or 4 feet, and in one section near Havre the colour does not reach the Chloritic Marl.

St. Jouin.

In going to the eastward some of the features just described as occurring at the base of the Cenomanian become lost, and the section seen at St. Jouin is somewhat different from that at La Hève. The Chloritic Marl, with the brown sandy seam and phosphates, is the same, but the succeeding siliceous beds have died out and are replaced by yellowish-white chalk containing comparatively little glauconite, and in this are lines of thin-skinned black cherts. Above this the rock for a short distance has a bluish cast.

Near the top of Bed 6 there comes in a course of grey gritty limestone, with green-coated nodules, much resembling the Totternhoe Stone of Norfolk and Suffolk. Still farther east, at Brunval, this bed thickens and is divided into two layers, separated by grey, glauconitic, gritty chalk. A marked bed of massive chert immediately beneath this can be followed by the eye from St. Jouin to Brunval.

This hard bed thins to the westward and is lost before Cape La Hève is reached. We believe, however, that the massive chert-bed which just underlies it is at about the same horizon as the five massive chert-beds at La Hève.

M. Lennier has minutely described the section seen at St. Jouin in an account published in 1884 of an excursion of the Société Géologique de Normandie to St. Jouin, Brunval, and Antifer. He makes the thickness of the Cenomanian at this point to be 118 feet 7 inches, which nearly coincides with our own measurement of 119 feet 6 inches. But his section does not appear to include the basement-bed, so that, if this be added, his estimate will be somewhat greater than ours. We here tabulate for comparison the section of St. Jouin as taken by M. Lennier and ourselves, some of Lennier's beds being grouped to save space.

	HILL, 1895.	Feet.	LENNIER, 1884.	Feet.
Bed 8.	Firm whitish chalk with layers of chert nodules, about	20	Compact grey chalk with nodules of bluish chert in layers	11½
	Greyish-white chalk divided into beds by layers of chert-nodules, bluish-grey in colour	15	Yellow or grey chalk, sandy, with layers of chert and black flint	26
Bed 7.	Grey glauconitic chalk, with hard calcareous masses and some cherts—many brown phosphatic nodules	10	Grey chalk with layers of cherts and many brown nodules; this bed is very fossiliferous	10
	Greyish-white chalk, slightly glauconitic, with layers of grey or black cherts	24–30	Grey glauconitic chalk with chert-nodules and layers of black flint	32
	Hard, grey, shelly, glauconitic chalk, with hard crystalline lumps and green-coated nodules	8-10	Hard, grey, sandy chalk in two beds with a course of sandy glauconitic marl between	10
Bed 6.	Conspicuous layer of cherts	1½	Thick band of mammillated flint.	1
	Yellowish-grey chalk divided into beds by courses of chert-nodules, bands of bluish-grey chalk at intervals	28	Yellowish chalk, with irregular layers of chert and beds of grey sandy chalk	26
			Bed of large black flints	9 in.
			Grey glauconitic chalk	9 in.
	Bluish-grey glauconitic chalk	3½	Siliceous bed	9 in.
	Yellowish-grey chalk with four layers of black cherts	5	Sandy glauconitic marl with siliceous concretions, thickness unknown.	
Bed 5. Chloritic Marl.	Bluish-grey, glauconitic, sandy marl, with black phosphate-nodules at the base	3½		
	Thin seam of brown sand, about	2 in.		
Bed 4. The Gaize.	Bluish-grey sandy marl, seen for 6 or 8 feet.			

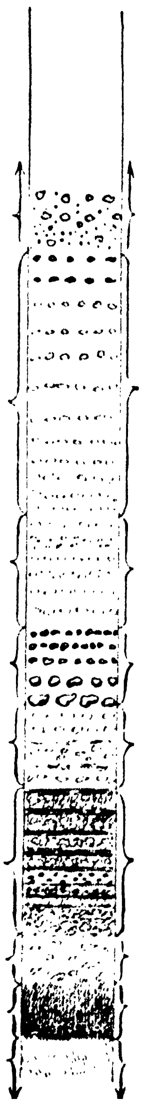
We were unable to see the marly seam which is taken by M. Lennier as the summit of the Cenomanian at St. Jouin; our measurements were taken to the base of a nodular bed having the unmistakable character of Melbourn Rock. There was apparently no representative of the marl with *Belemnitella plena* at Brunval.

It will be seen, on looking at the diagram facing this page, that above the hard bed at St. Jouin, and above the massive cherts at Cape La Hève, the Chalk has the same general facies, and the same description will apply to both.

Bed 7.

About 35 to 40 feet above the massive and conspicuous layers of chert at La Hève, and about the same distance above the marked hard bed described in the section at St. Jouin, there is a band of chalk containing many scattered phosphatic nodules of a brownish colour. These are most numerous between the chert-beds, and the chalk between them is often very glauconitic, rough and gritty to the touch. The phosphates do not occur with much regularity, and are more conspicuous at some points than at others. Beyond the fact of their occurrence there is no lithological break; they come in with chalk containing more glauconite than usual and pass away again in about 15 feet. Many fossils occur in this bed, but there

La Hève.


La Hève.
Ft. In.
Greyish-white chalk, with scattered cherts and brown phosphatic nodules.
Whitish-grey, slightly glauconitic chalk, divided into courses by grey cherts. Near the top are two marked beds of black cherts.
28 0
Yellowish-grey, slightly glauconitic chalk, divided into courses by chert-beds.
13 0
Yellowish-grey glauconitic chalk, divided into courses by five beds of massive cherts.
8 0
Yellowish-grey, slightly glauconitic chalk, with scattered cherts, divided irregularly into courses by hard siliceous layers or beds.
9 0
Beds of chalky material, indurated with silica, separated by courses of marly, very glauconitic yellowish-grey chalk.
14 9
Firm yellowish-grey glauconitic chalk, with hard siliceous masses like immature cherts.
5 0
Bluish-grey, very glauconitic, sandy marl, with hard masses and many black phosphate-nodules.
6 0
Sandy seam.
Bluish-grey, sandy, glauconitic marl.
Upper Greensand (Gaize).
…urses by chert-beds.
…chalk, with grey or …lines. Many brown
…y masses weathering
…with discontinuous …eparating the chert- …nitic. A few phos-
…with hard calcareous
…onitic chalk ; cherts
…with marked chert- …and hard concre-
…lk, enclosing hard …cherts. …scattered blue-grey …crystalline lumps.
…k, with a layer of
…two lines of cherts,
…itic chalk, divided
…in thin laminæ.
…courses by lines of …bluish-grey.
…conitic than below,
…ourses by four lines
…dy marl, with black
…l.

is little difference between its fauna and that of the beds below. Cephalopoda are rather more abundant, but are of the same species; *Holaster subglobosus* becomes common about 8 feet below this bed and ranges above it, at the same time *Epiaster crassissimus* and *Catopygus carinatus* either die out or become rare. The following is a list of the commoner fossils occurring in this central part of the Cenomanian, the first column showing those in Bed 6, and the second those in Bed 7. The letter L indicates species which are given on the authority of M. Lennier :—

	Bed 6.	Bed 7.		Bed 6.	Bed 7.
Porosphæra, sp.	*		*Ostrea canaliculata* (*lateralis*)	*	*
" *urceolata*	*		*Pecten asper*	*	*
Rhynchonella convexa	*	*	" *Galliennii*	*	
" *dimidiata*	*	*	" *Marrotianus*	...	*
" *Grasiana*	*	*	" *Puzosianus*	...	*
Kingena lima	*		" *elongatus*	*	
Terebratula arcuata	*		*Janira æquicostata*	...	*
" *capillata*	*		" *quinquecostata*	*	*
Terebratella Menardi	...	*	*Lima clypeiformis*	L	
Caratomus rostratus	L	*	*Spondylus striatus*	*	
Catopygus carinatus	*		*Pleurotomaria Archiaci*	L	
Cidaris vesiculosa	*	*	*Avellana cassis*	...	L
Holaster carinatus	*		*Aporrhais*, sp., cast.	...	*
" *subglobosus*	*	*	*Ammonites falcatus*	...	L
Epiaster crassissimus	*		" *Mantelli*	*	L
" *distinctus*	L		" *varians*	*	*
Pseudodiadema ornatum	*	*	" *Coupei*	*	*
" *Benettiæ*	*		*Turrilites costatus*	*	*
Discoidea subucula	*	*	" *tuberculatus*	*	*
Glyphocyphus radiatus	...	*	*Scaphites æqualis*	...	*
Salenia petalifera	L	L	*Hamites* sp.,	...	*
" sp.	*		*Nautilus*, sp.	...	*
Exogyra conica	*	*			

Bed 8.

Above the phosphates the chalk is featureless. It is, however, distinctly whiter and more free from glauconite; flint-like cherts continue to divide it into courses. Fossils are comparatively rare; we collected none from it.

The Turonian.

The base of the Turonian is well marked between St. Jouin and Brunval by a bed of hard nodular chalk, like that which we recognize in England as the Melbourn Rock. In fallen blocks on the shore fossils common to the base of the Middle Chalk occur plentifully, such as: *Inoceramus labiatus, Rhynchonella Cuvieri, Cardiaster pygmæus.*

IV. A Correlation of the Cenomanian Deposits in the Calvados, Orne, and Sarthe.

1. Calvados.

Having studied in detail the sections of the cliffs at and west of Cape La Hève, and having satisfied ourselves how much of the series corresponded to our Gault and Upper Greensand, and how much to our Lower Chalk, we desired to ascertain the stratigraphic relations of this combined Albien and Cenomanian series and that of the typical Cenomanian in the Orne and Sarthe.

This was a more difficult task, because no French geologist had explored the ground for this special purpose, consequently the exposures had to be sought for. Sections in the middle and upper part of the Cenomanian, such as occur near Honfleur, were of no use to us: what we required were exposures of the basement-beds, in order to judge how far the Havre equivalent of the Upper Greensand extended to the southward, and whether the base of the Cenomanian continued to present the same character as that exhibited by it at Havre.

We soon found that it did not, for the following section was seen at Moulineaux, about 2 miles S.S.W. of Honfleur, in a pit which had been recently dug in the side of a hill for the formation of a washing-place or reservoir. Descending order:—

		Feet.	Ins.
	Soil, chalk-rubble, fragments of chert and brownish clay	8	0
Cenomanian.	3. Yellowish-grey, soft, marly chalk, very glauconitic, and containing hard siliceous concretions, also many fossils: *Rhynchonella dimidiata*, *Rh. Grasiana*, *Megerlia lima*, *Ostrea vesiculosa*, spines of *Cidaris vesiculosa*	4	0
Cenomanian.	2. A bed of hard masses in soft grey and very glauconitic marl, with *Rh. dimidiata*, *Catopygus carinatus*, etc	3	3
Upper Greensand.	1. Dark grey, exceedingly glauconitic, calcareous marl, seen for	2–3	0

The material of Bed 2 resembles that of the Chloritic Marl of La Hève without the phosphates, the glauconite-grains being large, but the cementing-material of the hard masses proves to be calcite.

The overlying chalk is similar to that occupying the same position near Havre, its glauconitic grains being small, and we think there can be no doubt that the base of the Cenomanian was here exposed.

Passing to the valley of the Touques and proceeding by the high road leading from Pont l'Evêque to Lisieux, the next exposure noted was about 200 yards east of Les Forges, on the road leading to Blangy. Here a strong spring is thrown out, and yellowish-grey glauconitic chalk was shown just above it, while on the other side of the road a freshly-out ditch showed grey and very glauconitic marl, but without hard lumps similar to those of the basement-bed near Honfleur.

Blangy lies in a branch of the main Touques Valley. On the southern side of this valley, along the high road leading to the village, the outcrop of the Upper Greensand was evident in many places, but no good section was seen.

On the northern side of the valley the hills are more precipitous, and there occur several small pits in the basal part of the Cenomanian. In one of these yellowish-white glauconitic chalk was seen passing down into yellowish-grey marly chalk containing much glauconite, and in a small exposure 30 yards to the west this was seen to be underlain by grey calcareous marl containing much glauconite in large grains. Farther on, several small exposures in the bank showed this calcareous marl passing down into a greensand. There was no complete section, and no hard lumps were found, but it was evident that the Cenomanian passed down through a bed of marly glauconitic chalk to the greensand. Returning to the main road, the grey marl and glauconitic junction-bed were again seen in a ditch about 3 miles north of Lisieux.

At the village of Hermival, which lies in another minor branch of the Touques Valley, the Upper Greensand was well seen, by following a newly-cleared ditch by the side of the roadway, passing up into a grey glauconitic marl, at the top of which was a bed of hard crystalline lumps between 1 and 2 feet thick; this was overlain abruptly by yellowish-grey glauconitic chalk. A small spring seemed to issue from the junction of the two beds.

About 1½ mile south of Lisieux, just before coming to the village of St. Martin de Liette, is an interesting exposure in a large sandpit, which shows that the Carstone-like bed at the base of the Gault, to which we have drawn attention in the section of the cliffs of La Hève, persists thus far, though somewhat attenuated. The section is as follows:—

	Feet.	Ins.
Rubble of grey chert and sandy soil	2	0
Very glauconitic and rather marly sand	2	6
Dark grey, greasy clay	0	9
Coarse brown pebbly grit, with much fossil wood and many light-coloured phosphates	7	0
White micaceous sand .... about	40	0

The white micaceous sand is part of the 'Sables de Glos' (Corallian). On this rests the coarse brown grit, which is succeeded abruptly by the clay. We found no fossils in either, except the cast of a *Natica* in the brown grit, about 18 inches from the top; but M. Bigot, of Caen, informed us that he had found others in the same bed, and kindly sent them to us for inspection. Most of them showed a matrix of very glauconitic material, and we think that they have come from the very top of the grit (or Carstone) at its junction with the clay. Among them we could identify *Ammonites interruptus* (vars. *Deluci* and *dentatus*), *Pecten orbicularis*, *Cucullæa fibrosa* ?, and a large *Cyprina* or *Cucullæa*. There was also a *Natica* in a brown matrix, like that of our own specimen. The

ammonites are sufficient to prove the bed which yielded them to be of Lower Gault or Albien age.

From Lisieux, acting under the advice kindly given us by M. Bigot, the country south-east of the valley of the Touques, in the neighbourhood of St. Paul de Courtonne and Orbec, was next explored.

At La Haute Roche, about ¼ mile S.S.E. of Courtonne du Murdrac, the following section was seen:—

	Feet.	Ins.
Yellowish-grey chalk, slightly glauconitic, scattered grey cherts and ramifying siliceous concretions in discontinuous beds	4	0
Chalk similar to the above, with two beds of massive chert...	2	6
Yellowish-grey chalk, glauconitic, with scattered cherty or siliceous concretions	1	9
Yellowish-grey chalk, firm, slightly glauconitic, with large cherts arranged in discontinuous lines	10	0
Mealy, yellowish-grey, very glauconitic chalk, seen for	1	6

This exposure occurs in a low cliff capping the summit of a hill, and is not far from the base of the Cenomanian, which was estimated to be 12 or 15 feet lower than the bottom of this exposure. About this vertical distance glauconitic sand was well shown in the hedgerow and in the field below, the base of the Gaize being probably indicated by a spring and the boggy nature of the ground; if this surmise is correct, the Gaize and Gault cannot be much less than 30 feet thick at this point, and may be more.

The section can be followed for some little distance, but the junction-beds were not noticed.

About 300 yards S.S.E. of the church of St. Paul de Courtonne, 13 feet of whitish-grey, slightly glauconitic chalk was seen, with discontinuous lines of grey chert, and 30 yards farther on there was a course of hard, grey, lumpy chalk with many fossils, about 2 feet thick, making with the other a continuous section. The ground then dropped suddenly, forming a steep pitch, a feature constantly noticed at this horizon in many localities in Calvados, and below this it sloped gently to the banks of a brook some 50 yards away.

The soil was full of large glauconitic grains, evidently Greensand. A little farther S.E., in the next field, along the steep pitch of the ground already noticed, were many hard calcareous masses full of glauconite and of the same character as those of the junction-beds at Honfleur and Hermival, but the glauconitic grains were smaller. About ¾ mile farther S.E., opposite the turning of the road to Orbec, many specimens of *Pecten asper* occurred in lumps of hard chalk scattered along the top of the pitch, the material adhering to them being yellowish-white, slightly glauconitic chalk, not like the basement-bed which was seen in the banks of the brook 4 or 5 feet lower.

The basal beds of the Cenomanian were again shown about 300 yards east of the Chapel of St. Julien de Mailloc, in a small pit in a field. The section was as follows:—

	Feet.	Ins.
Rubbly broken chalk and soil	6–7	0
Smooth glauconitic chalk in two massive beds, weathering with a peculiar mealy touch when handled	5	0
Rough, lumpy, grey, glauconitic chalk, hardly nodular, but lumpy, the lumps being hard, with soft mealy chalk between, very fossiliferous	6	6

At or near Orbec are several large pits at this horizon showing the lowest part of the Cenomanian, but without exposing the actual base. The most important is a quarry close to the railway, halfway between the stations of Orbiquet and St. Martin de Bienfaite. Nearly 40 feet of chalk is here exposed and its general character may be understood by the following section. Descending order:—

	Feet.	Ins.
Smooth, yellowish-grey, mealy chalk, rather glauconitic ...	2	6
Rough chalk, lumpy, the lumps being in a mealy matrix .	2	0
Soft, yellowish-grey, mealy chalk with grey cherts	7	0
Rough, glauconitic, yellowish-grey chalk with hard lumps in a softer mealy matrix	5	0
Firm, glauconitic, yellowish-grey chalk	2	0
Firm, glauconitic, yellowish-grey chalk, with hard silicified masses—not chert	3	0
Softer glauconitic chalk, weathering in platy pieces	2	6
Bed of large separated cherts	0	6
Firm, yellowish-grey, glauconitic chalk, smooth, without lumps	9	0
A course of hard, lumpy, glauconitic chalk	3	0
Smooth, whitish-grey, glauconitic chalk	1	6

Although the general character of the chalk seen in this quarry agrees with that at the same horizon in this and other localities, we are unable to correlate the various beds, and it would appear that minor peculiarities do not persist in the way that frequently happens in the English Chalk. The rock at this horizon is usually yellowish, or ochreous white, or grey in colour, slightly but irregularly glauconitic, some beds containing more glauconite than others, the grains being small. It weathers down and gives off a dust which has a somewhat gritty, mealy texture, and is not the impalpable powder which results from the handling of English chalk.

It contains many concretions of a siliceous nature, sometimes merely silicified chalk; but often there is a nucleus of clear black or grey silica, which merges through the silicified chalk into the calcareous matrix which surrounds it, there being no rind. Well-defined chert-nodules are, of course, also common.

2. Northern Orne.

Continuing the exploration of the Touques Valley, evidence of the outcrop of the Greensand was met with in several localities, but no section was seen until Fauvaque was reached. Here a small quarry showed Greensand still underlain by a thin bed of clay, which in its turn rested directly on the Corallian—the Carstone-like bed being absent.

A mile north of Notre Dame de Courson a new section in a road-cutting was fortunately seen, showing about 9 feet of soft, exceedingly glauconitic sand, and about 100 yards north of this the section was carried higher in the bank of a short cutting in a lane. Here there occurred about 2 or 3 feet of greyish calcareous and rather marly sand with rusty markings. It contained many fragments of *Pecten asper*, and the material was very similar to that found at the summit of the Greensand at Vimoutiers, 6 miles southward. No hard calcareous masses were seen, but we think that this grey calcareous marl was undoubtedly the top of the Greensand.

Vimoutiers was the next place of interest, and we have heartily to thank M. Lecœur, of this town, for his kindness in accompanying one of us to the principal sections in the neighbourhood, and also for his generosity in adding some named specimens to our collection of fossils. Nowhere else was the whole Cenomanian so well shown as in the large quarries near here, which give almost a complete section from the Greensand below to the Craie marneuse at the top. Besides this, continuous railway-cuttings enable one, armed with proper authority, to study the upper part of the Cretaceous series far above the beds in which we had especial interest, and one could not help regretting that time allowed the study of the basal portion only. The following section was taken at a very large quarry, nearly a mile north-east of the church:—

		Feet.	Ins.
CENOMANIAN.	Soil, etc.	1	0
	Greyish, glauconitic, sandy chalk weathering to mealy dust, rather harder rough rock alternating with smoother layers, cherts scattered or in discontinuous lines	37	0
	Yellowish-grey, glauconitic, sandy chalk, rough, with hard irregular lumps (not nodules), softer chalk between	6	0
	Massive grey cherts, apparently a continuous bed	1	0
	Yellowish-grey, glauconitic, sandy chalk, rough and lumpy, softer mealy chalk between the lumps	1	6
	A line of separated cherts	0	9
	Yellowish-grey sandy chalk, rather glauconitic, with lighter patches, massive cherts irregularly scattered—passing down to	6	0
	Yellowish-grey, rather soft, mealy, and very glauconitic sandy chalk containing hard siliceous concretions	6	0
	A bed of detached, hard, calcareous masses, very glauconitic, forming a marked hard layer	1	0
UPPER GREENSAND.	Greyish-green, very glauconitic, calcareous, sandy marl with rusty markings, passing down to dark green glauconitic sand, which gradually became darker and was almost black at the base	10	0

The Corallian immediately underlies the Greensand, but the actual junction is not seen in this quarry.

The line of separation between the Cenomanian and the Greensand is sharply marked, and the lithological difference between the two is striking. The one is a yellowish-grey, slightly glauconitic chalk, the other is a green marly sand in which large grains of glauconite preponderate, and even at the top, which is most calcareous, they give a distinct greenish tint to the deposit. This green sand is so soft that it can be dug with the fingers.

No fossils of any kind rewarded a search in the Greensand, nor was the base of the Cenomanian very fossiliferous. Many of the cherts and siliceous masses were evidently sponges, too bulky to carry away.

Most of the section given above is in the zone of *Ammonites Mantelli*; the highest part of this zone, with the overlying Craie de Rouen, or zone of *Ammonites rotomagensis*, and the Craie marneuse is seen at the quarry at Lisores, about a mile north-west of the railway-station at Vimoutiers. About 40 feet of fine-grained, glauconitic, sandy chalk of the upper part of the zone of *Ammonites Mantelli* was here exposed, with courses of rough lumpy chalk, and cherts, some scattered and some in layers.

The base of the zone of *Ammonites rotomagensis* is marked by a bed of intensely hard, creamy-yellow, crystalline, and glauconitic chalk, containing the usual hard siliceous masses of partly-formed chert. A series of small pits showed similar hard beds alternating with layers of soft grey and very glauconitic marly chalk, so soft in places that it could be almost dug with the fingers. These beds were in turn overlain by the Craie marneuse, a whitish-grey, slightly glauconitic, marly chalk not unlike in texture to the top of our own Grey Chalk.

Thus the whole succession of the Cenomanian seen at Vimoutiers is as follows, the thicknesses given being supplied to us by M. Lecœur:—

		Feet.
TURONIAN.	Craie marneuse	10-14
CENOMANIAN.	Craie de Rouen or Zone of *Ammonites rotomagensis*	33
	Zone of *Ammonites Mantelli*	113 115
	Upper Greensand	10
	Corallian.	

Many of the fossils found in the Craie de Rouen are in light brown phosphate. We recognize in this Craie de Rouen Beds 7 and 8 of the section at Cape La Hève.

M. Lecœur, of Vimoutiers, has sent us the following list of fossils collected by him from the Craie de Rouen of that locality and permits us to publish it:—

List of Fossils from the Craie de Rouen.

us carinatus.	*Trigonia spinosa.*
	Avellana cassis.
Epiaster crassissimus.	*Fusus Espaillaci.*
Pseudodiadema variolare.	*Pleurotomaria*, 2 species.
Terebratula biplicata.	*Ammonites varians.*
—— *lacrymosa (ovata).*	—— *rotomagensis.*
lla alata (=dimidiata, Sow.).	*Scaphites æqualis.*
	Baculites anceps?
amarckii.	*Turrilites costatus.*
Ostrea pseudo-vesiculosa.	*Hamites simplex.*
Inoceramus cuneiformis.	*Nautilus elegans.*
Corbis rotundata.	· *carinatus.*

In addition to these we have obtained :—

Ostrea canaliculata.	*Cardium*, sp.
· *carinata.*	*Ammonites cenomanensi*
Janira .	*Turrilites tuberculatus.*

The fauna really differs very little from that of the zone of *Ammonites Mantelli*, except that in this locality some of the cephalopoda, such as *Ammonites rotomagensis* and *cenomanensis* and *Scaphites æqualis*, do not occur in the lower zone. Elsewhere, however—for instance, near Havre and in England—*Scaphites æqualis* ranges to the very base of the Cenomanian.

About 1¼ mile S.W. of Gacé there is a large quarry where the Corallian has been dug; a lane leads round its southern extremity, and here there occurred a complete section through the Greensand to the zone of *Ammonites Mantelli* as follows :—

		Feet.
	Rubble of chalk, cherts, and soil.	
CENOMANIAN.	Yellowish-grey, sandy, micaceous, glauconitic, siliceous 'chalk' (more than usually rusty-coloured, probably much weathered)	6–8
	A layer of hard very glauconitic, siliceous, partly crystalline masses	1
UPPER GREENSAND.	Exceedingly glauconitic, green-grey, sandy marl, passing down to very dark, marly, glauconitic sand, almost black at the base	9
	CORALLIAN.	——

Ammonites Mantelli and *A. navicularis* occurred in the yellowish 'chalk.'

Near Mortagne, along a field-path leading from Mortagne to Villers, the Greensand was seen in several places as one passed over the outcrop, but no section was found.

Near the railway-station at Villers, in a ditch by the roadside along the road towards Fiengs, it was constantly exposed. Returning from Villers by the road which joins the high road from Paris to Brest at La Jarretière, Greensand was seen in the fields adjoining the road, and at one point the plough had turned up many pieces of the hard crystalline bed at its summit.

Turning towards Mortagne, along the high road, about ¼ mile from the village of La Jarretière, the Greensand is exposed in a lane to the left much as it is at Gacé. Its character is the same,—a light, calcareous, marly sand, passing down to a deposit almost black in colour. The top is hidden; a wide dark band, visible for some distance away, betrays its outcrop in the arable fields, over which are scattered fragments of the hard bed. The estimated thickness of the Greensand here is 15 feet.

The yellowish 'chalk' with *Ammonites Mantelli* was seen to immediately overlie the Greensand in the cutting of the road to St. Hilaire les Montagne, about 100 yards nearer La Jarretière.

From the evidence gained by this traverse we think that after leaving Cape La Hève a lateral change takes place at the base of the Cenomanian; that the bed with black phosphates dies out before reaching Moulineaux, near Honfleur, and gives place to a bed containing hard crystalline masses; that between Lisieux and Vimoutiers this bed becomes condensed, as it were, until it forms a small and well-marked hard layer at the base of the 'Chalk.' If we are correct in this opinion, this hard layer is the true base of the Cenomanian, and the beds below ought to be excluded from this stage.

We have seen that the Gault at Lisieux is at the point of disappearance, and consequently we take the mass of the glauconitic sand south of that place to be the equivalent of the Gaize; but, as *Pecten asper* occurs in the sandy marls at the top of these, it would appear that a local or lenticular deposit representing the English zone of *Pecten asper* is present for some distance. Whether this enters into the 10 feet of glauconite at Vimoutiers we will not undertake to say, but we have no doubt that this 10-foot bed is the attenuated representative of our Upper Greensand, and that the beds above it are the equivalent of our Lower Chalk.

[*Note.* November 7th, 1895.—Since the above was written we find that Prof. de Lapparent has expressly separated this 'glauconie à *Ostrea vesiculosa*' of the Eure, Orne, and Maine from the Cénomanien ('Traité de Géologie,' 2nd ed. 1885, pp. 1041 and 1075). He classes it with the Albien, and considers it to be the equivalent of the Gaize of the Havre district; speaking of the Cenomanian of the Orne on p. 1075, he describes it as 'resting on the glauconie à *O. vesiculosa*.' This was a new departure, MM. Guillier, Bizet, and other French geologists having always regarded it as the basement-bed of the Cenomanian Series. It is satisfactory to find that we had independently arrived at the same conclusion as M. de Lapparent, and that, so far as Western France is concerned, we are in complete accord with his definition of the Cénomanien stage.

He does not venture upon any correlation of the western Cénomanien with English deposits, but includes the Warminster Greensand in his table of English equivalents. If, in his next edition, he were to omit this greensand, his table would express precisely our view of the subject.]

3. The Cenomanian Sands of the Southern Orne and Sarthe.

We now come to a region which has been well explored by Messrs. Paul Bizet and Albert Guillier. The great change from a chalky to an arenaceous facies begins to set in between Gacé and Mortagne, and, curiously enough, this occurs at the very top of the formation, beds of sand coming in above the 'Craie à *Ammonites rotomagensis*.' These are the 'Sables du Perche,' and it is interesting to find that they contain fossils which we are accustomed to associate with much older deposits (Chalk Marl and Upper Greensand). M. Bizet mentions, as common fossils, *Ammonites navicularis*, *Ostrea carinata*, *Rhynchonella compressa*, with many shells of *Exogyra conica* and *E. columba*.

Near Mortagne the sequence is given by M. Bizet[1] as follows:—

4. Sables du Perche à *Ammonites navicularis*.
3. Craie de Rouen à *Ammonites rotomagensis*.
2. Craie glauconieuse à *Ammonites Mantelli*.
1. Glauconie et argile glauconieuse à *Ostrea vesiculosa*.

The Craie de Rouen is a thick mass of chalk which is divisible into two parts or zones: (1) an upper zone of *Scaphites æqualis*, which consists of alternating beds of firm chalk and greyish marl; (2) a lower zone to which he does not assign any particular fossil, but which consists of chalk with nodules of greyish flint.

The Craie glauconieuse is evidently like that which we have described at Vimoutiers and elsewhere, but M. Bizet seems to include in it what we regard as the uppermost beds of the 'glauconie' or Greensand. Thus, in his excellent paper on the 'Profil géologique du Chemin de fer de Mamers à Mortagne,' he writes:— 'Above the greensand come more or less argillaceous marls and sands, then alternations of glauconitic sand and beds of a kind of greenish or yellowish chalk, always containing many green grains." He classes both these in the zone of *Ammonites Mantelli*, but we did not find that fossil in the argillaceous marl, and, as already stated, for us the base of the Cénomanien is at the top of this marl and at the base of the yellowish chalk.

Near Mortagne and Bellême the lowest Cretaceous deposit is the 'Glauconie à *O. vesiculosa*.' This is a sandy marl or clay, which in some places, and especially in the east of the department, contains phosphatic nodules; its thickness is only from 3 to 10 feet, and *Ostrea vesiculosa* is the sole fossil found in it. At Ceton, however, on the eastern border of the Orne, a representative of the Upper Gault or Gaize comes in below this 'glauconie'—a glauconitic clay with phosphatic nodules and casts of fossils, among which are *Ammonites inflatus*, *A. auritus*, and *Arca carinata*. *Ammonites splendens* has also been found in the same bed at Souancé, near Nogent-le-Rotrou.

It is clear, therefore, that the Upper Cretaceous sequence in the east of the Orne is nearly as complete as in the Calvados, and that it is merely a question as to where the line for the base of the Cénomanien should be drawn.

[1] Bull. Soc. Géol. Normandie, vol. viii. (1881) p. 40, and vol. xi. (1885) p. 58.

4. Sarthe.

Proceeding still southward, we find that the next change takes place in the lower portion of the Craie de Rouen, which becomes sandy and passes into grey sands with blocks of calcareous sandstone. Thus in the communes of Théligny and Lamnay a mass of such sand is intercalated between the 'Craie à *Scaphites*' and the 'Craie glauconieuse à *Ammonites Mantelli*.' The researches of M. Bizet in this district have established the following succession:—

	Feet.
5. Sables du Perche à *Rhynchonella compressa*, with *Ammonites navicularis* and *Trigonia*	+20
4. Craie à *Scaphites æqualis*, with *Ammonites varians*, *Turrilites costatus*, and *Pecten asper*	60 to 70
3. Sables et grès à *Perna lanceolata* et *Anorthopygus orbicularis*	130
2. Craie glauconieuse à *Ammonites Mantelli*, *Turrilites tuberculatus*, *Pecten asper*, etc.	80
1. Glauconie à *Ostrea vesiculosa*	25
	+325

Finally, towards the south-west, in the direction of Le Mans, the 'Craie à *Scaphites*' also undergoes a lateral change; beds of sand and sandstone set in, and the chalky marls thin out, till the whole is replaced by sands of various colours, grey, green, and yellow, enclosing large blocks of calcareous sandstone. These sands have yielded a large number of fossils, the numbers known to M. Guillier in 1886 being, of mollusca 200 species, of echinodermata 30, of bryozoa, corals, foraminifera, and sponges over 130 species. The larger number of d'Orbigny's types were in fact obtained from this portion of the Cenomanian series.

The 'Sables à *Anorthopygus orbicularis*' maintain their characters and thickness below the 'Sables à *Scaphites*,' and have also yielded many of the same fossils.

The Craie glauconieuse, however, partakes in the prevalent change, losing its calcareous ingredient, and passing into beds of fine micaceous sand and ferruginous clay, so different in appearance from Craie glauconieuse that they might have been referred to a lower horizon, were it not that they contain in places some of the characteristic fossils of the zone of *Ammonites Mantelli*, such as *Ammonites Vibrayeanus*, *A. falcatus*, and *A. rotomagensis*.

As regards the 'Glauconie à *Ostrea vesiculosa*' M. Guillier remarks:—'In the west of the department there exist beds of glauconitic material which seem to be the prolongation of these, but, as they do not contain fossils and are intimately united with the overlying beds (argile glauconieuse à minerai de fer), we have not separated them.' Clearly some further investigation of these beds is required, and we may hope that the survey of the Sarthe on which M. Bizet is now engaged will enable him to determine whether the *O. vesiculosa*-beds die out entirely, as we should think most probable, or whether some representative of them really does occur at the base of the ferruginous clays.

From the above description it will be seen that the Cenomanian, which in the Calvados and in the north of the Orne consists chiefly of calcareous and micaceous material, is, near Le Mans, wholly represented by sands with a base of glauconitic clay. M. Guillier does not give the complete sequence at Le Mans in one view, but from his account it appears to be as follows:—

		Feet.
Sables supérieurs à *Rhynchonella compressa*	about	54
Sables et grès ferrugineux à *Scaphites æqualis* } Sables et grès à *Trigonies* et *Perna lanceolata* }	„	230
Argile glauconieuse à minerai de fer		30 to 50
	About	330

All these sands, and part, at any rate, of the basal glauconitic clay, are without doubt the correlatives of the Cenomanian of Cape La Hève, as defined by M. Lennier and ourselves. In other words, we do not believe that the 'Grès du Maine,' as the central group of sands has been called, includes any representative of our Upper Greensand, but that it is merely a littoral deposit of the age of our Lower Chalk. The palæontological questions raised by this conclusion remain to be discussed. Our view of the correlation of the Cenomanian deposits in the West of France and South of England is shown in the Table facing p. 172.

V. The Minute Structure of some of the Beds in England and France.

The Cenomanian of Devon.

In hand-specimens the gritty limestone which forms the base of our zone of *Ammonites Mantelli* in the Devon series, and which is known as Bed 10 of Mr. Meyer, presents on its fractured surface a coarse, granular texture, sparkling with broken quartz-grains, often as large as a pea, and with calcitic crystals; not unfrequently, however, it is smoother and more compact, and sometimes seems to include pebbles of a finer material. When thin sections are examined under the microscope the rough, coarse-grained specimens are seen to be a sand composed of shelly fragments, minute portions of what seems to have been a previously consolidated deposit, foraminifera, and a few sponge-spicules. Large quartz-grains, some angular and some well rounded, are plentifully scattered through this sand, with here and there a grain of glauconite. The whole is cemented together by a clear crystalline calcite into a gritty limestone. In other parts of the rock the matrix seems to have been formerly a fine calcareous paste, which is now in the condition of a finely granular crystalline limestone.

As a whole, the structure of the shelly fragments is obliterated in the general crystallization, and their derivation is uncertain: their general outline does not suggest the prisms of

but rather pieces of *Pecten*, fragments of the tests or spines of echinodermata, polyzoa, and perhaps coral.

Foraminifera are not uncommon, the genera represented being chiefly *Textularia*, *Cristellaria*, and *Rotalia*; *Globigerina* is rare or absent, and calcareous 'spheres' do not occur at all. Although free sponge-spicules are uncommon, there is much sponge-structure (? of calcisponges).

Bed 11.

Bed 11 resembles the finer and more shelly portions of Bed 10, and specimens from Hooken Cliff, Beer Head, and elsewhere present the same character. Like Bed 10, it consists of calcareous particles derived from various sources, foraminifera, sponge-spicules, with many quartz- and glauconite-grains, the latter being more common than in Bed 10. The whole is cemented together by crystalline calcite.

Bed 12.

This bed is a dense, hard, crystalline limestone, with smooth fracture, containing many grains of quartz and glauconite, those of glauconite being still more abundant than in Beds 10 and 11.

Examination of thin slices proves it to be a true chalk, having a matrix of fine, amorphous, calcareous matter, now converted into granular calcite, in which are scattered a few shelly fragments, foraminifera, and some sponge-spicules. Spheres are common—the general aspect being that of certain specimens of Chalk Marl or Grey Chalk. But the rock in other parts contains many coarse shelly fragments and large glauconitic grains; these areas, though well defined, are not sharply marked off, and seem to be integral portions of the rock.

Bed 13. *Hooken Cliff.*

The structure of Bed 13 seems to vary at different places, but more examples are necessary to make sure of this point. The type may be taken as the marked zone of *Belemnitella plena* at Hooken. Here the matrix consists of fine amorphous calcareous matter and minute calcitic crystals. A few coarse fragments occur which can be identified as shell, and spheres and small-sized foraminifera are common. The feature of the rock is the abundance of large angular and rounded quartz-grains, and large grains of glauconite. The whole is loosely compacted, and forms a friable gritty stone.

The lower part of this bed has a somewhat different aspect. It is a compact glauconitic chalk, full of quartz-grains and coarse shelly fragments: variety of structure in the latter indicates derivation from various sources. A specimen supposed to be 13, from between Lyme Regis and Pinhay, shows a structure which approximates to that of Bed 14—the glauconitic base of the Middle Chalk

Base of the Middle Chalk.

Specimens from Lyme Regis, Bindon, Beer Head, and Branscombe show that the usual change takes place, and that the compact glauconitic chalk at this horizon consists chiefly of spheres thickly packed in the fine calcareous material of the matrix. *Globigerinæ* are among the most common foraminifera, but are not very abundant, and the shelly fragments consist chiefly of *Inoceramus*-prisms. Large quartz- and glauconite-grains still characterize the deposit, but they pass away in about 3 feet, and the rock has then the usual characters of Middle Chalk.

The Upper Greensand (or Gaize).

Cape La Hève.

For the purposes of this paper it is only necessary to describe the minute structure of the upper part of the Upper Greensand (the Gaize) in order to show that the material of which this division is composed differs considerably from that of the overlying Cenomanian.

Viewed under the microscope in thin sections, the matrix of the Greensand is seen to consist largely of fine, amorphous, siliceous matter, probably silicate of alumina, intermingled with which are minute calcareous particles. There are very few foraminifera, and not many shell-fragments or sponge-spicules. Globules of colloid silica are present, but not abundant. The proportion of quartz-sand is large, but the grains are small and angular: mica-flakes may be recognized. Rather large grains of glauconite are common, but not abundant. The rock compares well with a specimen of the upper part of the Upper Greensand of the Isle of Wight, taken from Culver Cliff, except that the grains of quartz and glauconite are distinctly larger.

Isle of Wight.

At the top of the Upper Greensand grains of glauconite become very abundant, and these and the quartz-grains are coarser, and the rock more calcareous. Specimens from Beds 2, 4, and 5 (see p. 105) from Collins Point show distinctly the commencement of a transition from Upper Greensand conditions to those of Chalk Marl.

The Cenomanian of France.

The Chloritic Marl of Cape La Hève.

The bed containing many black phosphates, which we take as the equivalent of the Chloritic Marl, will not compare in its minute structure with that of the Isle of Wight. It is a less calcareous deposit, it contains more fine inorganic material, and the grains of quartz and glauconite are more numerous and larger: indeed, as already mentioned on p. 121, some of the former are small pebbles. There is a little colloid silica, but few sponge-spicules, shell-fragments, or foraminifera.

The rock, as a whole, when viewed in thin section under the microscope, resembles more nearly the Cambridge Greensand than any of our specimens of Chloritic Marl.

Bed 6.

Seen from a short distance, the yellowish-white chalk into which the Chloritic Marl quickly passes, and which forms the major part of the Cenomanian in the cliffs between St. Jouin and Cape La Hève, looks like the rock we are accustomed to see on this side of the Channel; but a striking difference is seen in the lines of massive cherts which occur at irregular intervals from near the base to the summit.

A more critical examination shows that the lower part of the Cenomanian, all that included in Bed 6, possesses peculiarities not found in the Chalk of England. These are comparative lightness in the hand, a certain amount of gritty mealiness to the touch; and it is everywhere speckled by glauconitic grains, and a few minute mica-flakes sparkle on its fracture.

These peculiarities extend through Bed 6, and then there is a gradual passage to that white pulverulent limestone with which we are familiar.

When a thin section of Bed 6 is examined under the microscope, the matrix is found to be made up partly of fine, amorphous, calcareous matter, mixed probably with a small proportion of fine inorganic material, and partly of calcite in the condition of definite though minute crystals. The rock is full of shelly fragments, the derivation of the larger part of which is uncertain, but prisms of *Inoceramus*-shell are clearly less numerous than in shelly English chalk; such fragments as show structure are more frequently those of *Pecten* or portions of the spines or tests of echinodermata.

Foraminifera are present, but are not very numerous, the forms most in evidence being *Textularia*, *Cristellaria*, and *Rotalia*; *Globigerina* is rare, and spheres do not occur at all.

Intermingling with these calcareous elements are many spongespicules whose silica is invariably in the colloid state. These are sometimes closely packed, sometimes widely separate, but they are always present in greater number than in any English Chalk, except, perhaps, selected specimens of siliceous Chalk Marl.

Permeating the whole mass in single globules or aggregations of globules, is a large amount of colloid silica.

Glauconitic grains of large size, compared with those of our Lower Chalk, are seen in all specimens, sometimes in great abundance, and glauconite may also be seen infilling the spicular canals and the chambers of foraminifera.

Quartz-grains are common, but the quantity varies much in different specimens; they are everywhere more numerous and larger than in the English Chalk Marl, and some are angular.

This general description will apply to the whole of Bed 6 between St. Jouin and Cape La Hève. Sometimes the fine material preponderates, there are fewer quartz- and glauconite-grains, and the

chalk has a correspondingly denser texture. In other specimens, especially where sponge-spicules are numerous and there is much colloid silica, the fine and denser material seems to be in isolated grains or patches, and the rock has a granular aspect on its fractured surface. These grains seem to consist of fine calcareous material cemented by colloid silica or amorphous siliceous material.

The structure of the rock, then, somewhat resembles that seen in Beds 10 and 11 of the Devon Cenomanian, namely, separated calcareous fragments cemented together. The similarity is even carried further by the absence of *Globigerinæ* and 'spheres,' and by the comparative rarity of *Inoceramus*-prisms, while shelly particles, whose derivation is uncertain, abound in both deposits.

The differences between Bed 6 of La Hève and Bed 11 of the Devon series are the abundance of sponge-spicules and colloid silica in the former, and the greatly superior size of the glauconite- and quartz-grains in the latter. Moreover, the rock of Bed 6 never becomes a crystalline limestone, and is usually in a condition which admits of its particles becoming readily detached.

Hard beds and semi-crystalline lumps do occur, especially at St. Jouin, but nothing in the specimens we brought home, either from this locality or La Hève, completely parallels the granular structure of Beds 10 and 11 of Devon: in one from Vimoutiers, however, this structure is almost exactly reduplicated.

The presence of so much quartz and glauconite, the abundance of sponge-spicules, and the absence of *Globigerinæ* and spheres seem to show that this part of the Cenomanian was laid down in shallower water and nearer a coast-line than the English Chalk Marl.

Beds 7 and 8.

From near the base of Bed 7 the rock passes to a deposit which we may compare with our Grey Chalk. It consists of the usual amorphous calcareous matter, in which are scattered small shell-fragments, a few calcareous spheres and foraminifera. *Globigerinæ* continue rare. Sponge-spicules occur, but are less numerous, and there is little or no colloid silica. The Chalk at this horizon differs from its English equivalent in the presence of sponge-spicules, and in the occurrence of grains of glauconite and quartz. It is true that minute particles of both these minerals are to be seen far up in the Grey Chalk in the neighbourhood of Warminster and Devizes, but neither are found commonly in the Chalk of the Isle of Wight, which approaches most closely (so far as distance is concerned) to that of Cape La Hève.

Specimens taken from the base of the Turonian at Brunval show that the Chalk at this horizon is full of 'spheres' and *Inoceramus*-prisms, and is similar to that at the base of our Middle Chalk.

Calvados and Orne.

South of the Seine we confined our examination of the lithological characters of the Cenomanian to Beds 5 and 6. In this direction we saw nothing corresponding to the 'Gaize,' and where the top of Bed 4 was exposed the material was a soft and exceedingly glauconitic sand. A specimen from Bed 5, near Honfleur, compares with the base of Bed 6 at La Hève rather than the Chloritic Marl (Bed 5), except that it contains so many large glauconitic grains, quartz-grains being in rather small quantity. Neither do sponge-spicules or colloid silica occur commonly in this specimen. The cementing-material of the hard lumps found in this bed is crystalline calcite.

Southward of Honfleur we find a steady increase in the amount of quartz-sand and organic silica in Beds 5 and 6.

Thus, at Blangy, the matrix of a specimen from 10 or 12 feet from the base of the Cenomanian consists—judging by the eye—of at least 50 % of globular colloid silica, and the amount of sand-grains (quartz) mingled with this is greater than in any specimen from La Hève. Mica-flakes can also be recognized, and among the sand are grains other than those of quartz. Glauconite is present as usual, there are a few shell-fragments and much amorphous calcareous matter; sponge-spicules are common.

Specimens from Orbiquet taken at a higher horizon, one about 20 feet and another from about 45 feet above the base of Bed 6, show a similar increase in the amount of colloid silica and terrigenous material, the relative proportion of this decreasing upwards.

We regret that we omitted to secure a series of specimens from Bed 6 at Vimoutiers. Our knowledge of the minute structure of the Chalk here is obtained from that adhering to our fossil specimens, their height from the base of the bed being uncertain. Such specimens show that the conditions noted at Orbiquet continue to this point without much alteration.

One specimen showing a structure somewhat similar to that of Bed 11 has already been alluded to.

Still farther south we find that the base of Bed 6 has completely changed from a calcareous to a siliceous rock, comparable with the Malm of our Upper Greensand.

At Gacé, in the hard bed at the base of the Cenomanian, the equivalent of Bed 5 at Cape La Hève, the cementing-material is not calcite but silica, derived probably from the abundant spicules in the deposit, and much of this silica has passed from the colloid to the chalcedonic condition. The so-called 'Craie' which overlies the basement-bed is so completely siliceous that the reaction in acid is of the slightest, while at still higher horizons the deposit is not a chalk at all, but a sandy, micaceous, glauconitic, calcareous silt, with many sponge-spicules, amongst which the reniform spicules of *Geodia*[1] are common.

[1] Identified by Dr. G. J. Hinde.

Hence it is not surprising that the fauna of the French Cenomanian should differ considerably from the fauna of the Lower Chalk, although we firmly believe that they existed contemporaneously.

VI. Critical Remarks on some of the Fossils.[1]

The preparation of the following lists of fossils has involved a considerable amount of critical work, in which we have been greatly assisted by Mr. C. J. A. Meÿer, F.G.S., and Dr. G. J. Hinde, F.G.S. Mr. Meÿer has collected and studied the fossils of the Devon cliffs for the last twenty-five years, and has bestowed much time and care upon the identification of the various species of echinoidea and mollusca. The differences between the lists of these classes of animals now given and those in his paper on the Beer Head sections (Quart. Journ. Geol. Soc. vol. xxx. 1874) are chiefly due to his own researches, the results of which he has generously communicated to us. They have resulted in some corrections and in many fresh identifications among the fossils in his unequalled collection. Some of the specimens in this collection have already been figured by Lycett and Davidson in the publications of the Palæontographical Society, and many others are awaiting the preparation of other special monographs.

To Dr. Hinde we are indebted for examining, and naming so far as possible, all the sponges, hydrozoa, and polyzoa collected by ourselves in Devon and in France.

In order to explain the appearance of certain names in the lists of fossils, we have thought it desirable to set forth the results of these combined investigations and to make some critical remarks on those species which are interesting, either from their being unknown in England or from our having found a difficulty in identifying them. In several cases also we have been able to determine the identity of English and French species which had previously borne different names, and we think that such *rapprochements* will be welcomed on both sides of the Channel.

Sponges.

Stauronema Carteri, Sollas, Ann. Mag. Nat. Hist. ser. 4, vol. xix. (1877) pls. i.–v.

This fossil was first found by one of us in the so-called 'Upper Greensand' above the Gault at Folkestone in 1876, and was recognized by Prof. Sollas as a new and peculiar form. In describing it, however, he stated that it occurred in Gault and Upper Greensand, having understood that the original specimens came from the Folkestone Gault, and possessing a specimen from the Isle of Wight which he believed to have come from the Upper Greensand.

We think that the latter must have come from the Chloritic Marl of the Isle of Wight, in which the fossil is common, while we have never seen one from the Upper Greensand. We agree with

[1] Mr. Jukes-Browne is responsible for this section of the paper.

Mr. F. G. H. Price in regarding the glauconitic sand above the Gault at Folkestone as Chloritic Marl, not Upper Greensand. We have also found *St. Carteri* in the Chloritic Marl with phosphatic nodules near Devizes and Warminster, and Dr. Hinde informs us that it occurs at the same horizon at Eastbourne and Selborne. It is clearly, therefore, a fossil especially characteristic of this horizon, though it may possibly range a few feet up into the Chalk Marl.

We are also informed by Dr. Hinde that there are specimens in the British Museum from La Hève, and we are now able to say that it is common there in what we regard as the equivalent of the Chloritic Marl, namely the basal bed of the Cenomanian, and in the bottom of the overlying bed, but at no higher horizon.

Echinodermata.

GONIOPHORUS, sp.

A small specimen from the Chloritic Marl, which has all the characters of this genus, but differs from *G. lunulatus* in several respects. The apical disc, instead of being in low relief with a large aperture or periprocte, has its edges raised into rough tubercular ridges, which, with the similarly raised edges of the periprocte and a set of transverse bars or carinæ, make a curious pentangular pattern in five compartments surrounding the periprocte. These ridges are not plain and straight, as in *G. lunulatus*, but curved, so that the outline of the pentagon is irregular.

The test is less elevated than in *G. lunulatus*; there are only four tubercles in a row on the interambulacral areas, and the lower tubercles are very small, there being only three large ones on each area. The ambulacral areas are very prominent, and swell out towards the mouth.

Whether this is more than a very aberrant variety of *G. lunulatus* must depend on the discovery of others with the same characters; but it differs so much from the types figured by Cotteau and Wright that we felt the desirability of calling attention to it.

CODIOPSIS DOMA, Ag.

This sea-urchin has not previously been found in England, and, as it is specially characteristic of the Cenomanian of the Sarthe, its occurrence in Devon is interesting. The determination is due to Mr. C. J. A. Meyer, in whose cabinet the only known English specimens are. M. Bizet having kindly sent us two specimens of the large inflated form of the species, we forwarded these to Mr. Meyer, who reports that his are quite small in comparison. Probably they belong to the variety *C. pisum* of Desor.

HEMIASTER BUFO, Desor, in d'Orb. 'Pal. Fr. Terr. Crét.' vol. vi. p. 227, pl. 873.

This is a common species in the North-west of France. It is especially abundant at Blangy, Vimoutiers, and Villers-sur-Mer, but

no specimen came to hand from Cape La Hève, though d'Orbigny quotes it from there. It is a well-marked species, much more elevated than *H. minimus*, the anal area being very high and rising almost vertically from the base.

We have not seen anything like this species in England, and Mr. Meÿer informs us that the *Spatangus bufo* of his Devon list in 1874 was a mistake, a better specimen having enabled him to identify it as *Hemiaster Morrisii.* Mr. Sharman, to whom we sent specimens, compared them with all the Cretaceous Hemiasters in the Jermyn Street Museum, and did not find any resembling them.

HOLASTER SUBORBICULARIS, Brongn., figured by d'Orbigny, 'Pal. Fr. Terr. Crét.' vol. vi. p. 93, pls. 814 and 815. *Hol. suborbicularis*, Wright, 'Brit. Cret. Echin.' Pal. Soc. Monogr. p. 314, pl. lxxiv. fig. 1.

We do not think that the figures above referred to represent the same species. D'Orbigny's figure is that of a rather large cordiform urchin, much resembling *Cardiaster fossarius.* He describes it as specially characterized by the bulging out of the under surface in the hinder part, so that its greatest height is in this posterior region. Moreover it has a depressed anal area, and the vent is small and placed in the upper part of this area. The anteal sulcus is rather deep.

Dr. Wright's figure does not show these characters; there is no such marked anal area: the vent is large and not very high up. There is no such prominent basal protuberance. The test is very different in shape, and is very much smaller. He himself says that 'the English specimens are small and resemble the urchin described as *Holaster cenomanensis*, d'Orb., which, however, is only a small variety of *Hol. suborbicularis*.' He also states that it occurs plentifully in the Chalk Marl and in its glauconitic basement-bed.

This last statement is incomprehensible to us, as we have collected largely from those beds, but have seen very few specimens that will compare with Wright's figure of *Holaster suborbicularis*, and none like d'Orbigny's figure. Moreover, in Dr. Barrois's well-known 'Researches in the Cretaceous Formation of England' we find only one mention of *Holaster suborbicularis* (?), and this is from the Upper Greensand.

Mr. Meÿer informs us that he has some specimens from Bed 11 in Devon which agree with Wright's figure and a few which come near to that of d'Orbigny. We have therefore admitted both forms into our list.

HOLASTER, sp.

One of the commonest echinoderms in the zone of *Ammonites Mantelli* on the Devon coast is a form which differs from any yet described. A single specimen might be taken for a small elevated and oval variety of *Holaster subglobosus*; but, as that species occurs in the same beds and exhibits individuals of all ages, this form is either a different

species or a well-marked and unusual variety of that species. It is generally rather over an inch long and rather less than an inch broad, and about $\frac{13}{16}$ inch high. It is inflated below, and the vent is placed high. The anteal sulcus is bounded on each side by a ridge, which swells out near the top and gives a peaky character to this part of the test.

Mr. Sharman informs us that it comes nearest to a specimen in the Museum at Jermyn Street from the Middle Chalk of Dover, to which Prof. Forbes attached the MS. name of *Cardiaster Cockburni*.

PYGURUS LAMPAS, De la Beche, Wright, 'Cretaceous Echinodermata,' p. 258, pl. lviii. fig. 1.

The original specimen of this sea-urchin was found by Sir H. De la Beche near Lyme Regis in what he took to be Upper Greensand; but as it has never been found again in the Upper Greensand of Devon, and as Mr. Meÿer has obtained a specimen from his Bed 10 at Dunscombe, it probably came from the same horizon near Lyme Regis. Many of the blocks on the shore west of Lyme consist partly of the topmost bed of the Greensand and partly of the quartziferous grits (Beds 10, 11, 12), and De la Beche might well have regarded the whole mass as Greensand, for what looks like the base of the Chalk succeeds No. 12 (see p. 111).

This species is occasionally found in the Cenomanian of Le Mans, and also occurs at Fouras in the Charente Inférieure; it is therefore a conspicuous link between the Cenomanian of Devon and Western France.

SALENIA CLARKII, Forbes, in Wright, 'Cretaceous Echinodermata,' p. 177, pls. xxxviii., xxxix., & xlii.

A large *Salenia* occurs in the lower part of the Devon Cenomanian Bed 11, and again in the highest bed (13). It comes nearer to *S. Clarkii* of the Lower Chalk of Dover than to any other figured species, though it does not quite agree with Dr. Wright's type. A large specimen measuring more than an inch in diameter has been deposited in the Museum at Jermyn Street.

SALENIA PETALIFERA, Ag., var.

Some of the specimens referred to this species also differ in some respects from the type, and somewhat resemble *S. scutigera*, Gray. The zone of small tubercles on the interambulacral areas is very narrow and sinuous, and the apical plate exhibits some characters which, if constant, would differentiate it from *S. petalifera*.

Polyzoa.

CERIOCAVA RAMULOSA, Mich., sp., 'Icon. Zoophyt.,' and d'Orbigny, 'Pal. Fr. Terr. Crét.' vol. v. p. 1017, pl. 788. figs. 11 and 12.

This is a large coral-like organism, branching dichotomously, often 4 or 5 inches in length, and consisting of a number of con-

tiguous angular tubes which radiate outward and upward from a central axis. It is a very abundant fossil in the basal part of the zone of *Ammonites Mantelli* in Devon, especially at Dunscombe, Weston, and at Beer Head.

Specimens having been sent to Dr. G. J. Hinde, he reported that they strongly resembled the *Chætetes ramulosus* of Michelin found in the Cenomanian of the Sarthe. Subsequently M. Bizet, of Bellême, sent us a specimen found at Condrécieux (Sarthe), which appeared to be the same fossil. Dr. Hinde informs us that d'Orbigny placed Michelin's species as a polyzoan under the name of *Ceriocava ramulosa*; but he thinks that when the specimens are more carefully examined it will be found generically distinct from *Ceriopora* or *Ceriocava*.

In Morris's 'Catalogue' (2nd ed. 1854, p. 120) it is placed under *Ceriopora* and said to occur in the Greensand of Faringdon.

DEFRANCIA (PELAGIA) EUDESII, Mich.

This is another remarkable fossil, having a wonderful resemblance to a small expanded cup-coral; but it was recognized by Dr. Hinde as the polyzoan above named, which Michelin describes as common in the 'Craie chloritée' of Vaches Noires and in the 'Grès vert' of Le Mans. Only one specimen has been found in the lowest layer (Bed 10 of Meyer) of the *Mantelli*-zone near Branscombe.

MICROPORA.

The two species of *Micropora* entered in the list of Devon fossils, and numbered 4 and 5 respectively, are recognized by Dr. Hinde as occurring also among the specimens collected from the Chloritic Marl near Cape La Hève, although he is at present unable to identify them as described species.

Brachiopoda.

RHYNCHONELLA DIMIDIATA, Sow., and RH. ALATA, Brong.

In Guillier's 'Géologie de la Sarthe' (1880), and in some of M. Bizet's papers on the geology of the Orne and Sarthe, we find *Rhynchonella alata*, Lam., stated to be a common Cenomanian shell: but Davidson ('Brit. Cret. Brach.' vol. i. p. 82) mentions that MM. d'Orbigny and Deshayes agree with him in considering the *Rh. alata* of Lamarck as merely a synonym of *Rh. vespertilio* of Brocchi.

Later, in his 'Supplement,' when discussing *Rh. dimidiata*, Davidson states that the names *alata* and *gallina* were given by Brongniart to symmetrical forms of this shell, and *dimidiata* by Sowerby to the unsymmetrical form. It is therefore the *Rh. alata* of Brongniart, and not of Lamarck, which is the common Cenomanian shell.

Both varieties are very abundant in the Cenomanian of Devon,

and we have compared them with a number from different localities in France. There is no doubt about the identity of the English and French forms, and it is desirable that Sowerby's name should be recognized in France as it is in England and Germany. *Rh. convexa*, Sow., also occurs in the French Cenomanian.

RHYNCHONELLA WIESTII, Quenst. (1871), and Davidson (1874), in Supplement to 'Brit. Foss. Brach.' p. 66, pl. viii. fig. 31.

The shells referred by Davidson to this species are very common in Bed 13, the sandy chalk which overlies the zone of *Ammonites Mantelli* in Devon. It is a much more variable species than Davidson seems to have supposed, for he describes it as having 'about 30 or 32 rounded ribs,' and adds that it approaches most nearly to *Rh. Grasiana*, 'of which it may perhaps be a large variety.'

Having collected many specimens from this bed wherever it is found, we cannot agree with Davidson. The shell seems to us much more closely allied to *Rh. Cuvieri*, from which it can only be distinguished by having, as a rule, fewer and larger ribs. The average number seems to be 24 or 26, but there are forms which have as few as 18 and others which have as many as 30; the former resemble *Rh. Mantelliana*, except that the ribs are not angular, and the latter come so near to the broader varieties of *Rh. Cuvieri* that, when placed beside them, they are indistinguishable.

Although both the names *Cuvieri* and *Mantelliana* have been admitted into our list, we believe the specimens so named are extreme varieties of one species, which may be called *Rh. Wiestii*, and may be regarded as the ancestor of *Rh. Cuvieri* and *Rh. reedensis*, Eth., which occurs still higher in the zone of *Holaster planus*.

TEREBRATULA TORNACENSIS, d'Arch., Mém. Soc. géol. Fr. ser. 2, vol. ii. p. 316, pl. xviii. fig. 3, and varieties figs. 4–5.

This species was founded on specimens from the Tourtia of Tournay, and as this deposit is now known to be the littoral facies of the Cenomanian in Hainaut, and of later date than the zone of *Ammonites inflatus*, the occurrence of Tourtia forms in the Cenomanian of Devon and Sarthe is not surprising.

When Davidson first described the Faringdon fossils in 1852 he identified certain forms as *T. tornacensis*, var. *Roemeri*, d'Arch., though he was evidently for some time in great doubt about them (see 'Brit. Cret. Brach.' vol. i. p. 62). At that time he imagined that the Faringdon Sand was of Upper Greensand age, and, as the Tourtia was then supposed to be a sort of combined Lower and Upper Greensand, he saw no reason why a Tourtia species should not occur at Faringdon.

It seems, indeed, to be a fact that some of the forms of *T. depressa* and *T. tornacensis* occurring in the Tourtia are practically indistinguishable from varieties of *T. depressa* and *T. sella* which occur in the Lower Greensand of England; but the typical form of *T. torna-*

censis is certainly different from the typical *T. sella*, so that it is only the smaller varieties and the distorted forms which resemble one another.

Subsequently ('Supplement,' 1874, pp. 35, 36), and after correspondence with Mr. Meyer, Davidson was led to alter his opinion so far as to admit that the forms previously attributed to *T. tornacensis* were really only varieties of *T. sella*.

We agree with Mr. Meyer in regarding *T. tornacensis* as essentially a Cenomanian species, and we are able to state that it occurs in the typical Cenomanian of Le Mans, where it seems to have been confused with *T. biplicata*. M. Bizet has sent us three specimens under the latter name which in the opinion of Mr. Meyer and ourselves are typical *T. tornacensis*, differing from *biplicata* by the very characters pointed out by d'Archiac.

In Devon a few specimens have been found by Mr. Meyer in the beds described by him as 11 and 12 at Beer Head.

Whether the real *T. biplicata* occurs near Le Mans as well as *T. tornacensis* we have no means of knowing, but it does not seem to occur in Devon and it does not occur in the Tourtia of Tournay; it is common in the Chloritic Marl of the Isle of Wight, and occurs in that of Havre, as well as at Orbiquet (Calvados) and Vimoutiers (Orne).

TEREBRATULA ARENOSA, d'Arch., *op. cit.* p. 324, pl. xxi. figs. 1–3.

This is another Tourtia form recognized by Mr. Meyer in the Devon Cenomanian. It is a small globose species, the surface of which bears scattered granules or small tubercules with depressed summits, so that they resemble minute craters. It might easily be passed over as a globose form of *Megerlia lima*.

TEREBRATULA VERNEUILII, d'Arch., *op. cit.* p. 326, pl. xx. fig. 4.

This shell is not likely to be mistaken for any other species, as it bears a very remarkable ornamentation on both valves. They display a series of short, strong ridges, arranged in concentric rows and separated by oval indentations or hollows, so that the shell seems covered by a raised crochet-work pattern. The hollows are deepest at the top, and those of one row lie below the ridges of the row above. In the adult shell these ornamental ridges die away towards the edge of the shell.

Mr. Meyer has found this form in the same bed at Beer Head as that which contains *T. tornacensis* and *T. arenosa*.

TEREBRATULA CAPILLATA, d'Arch., and T. SQUAMOSA, Mantell.

We think that there is a much closer connexion between these two species than has hitherto been supposed. In discussing the relations of *T. capillata* Davidson only distinguishes it from *T. depressa*, to which d'Orbigny had imagined that it had some resemblance; and in describing *T. squamosa* he does not mention *T. capillata*. Yet

it is only necessary to look at plate v. of his Monograph, where both shells are figured, to see how nearly they approach one another through the least lamellose variety of *T. squamosa* (fig. 11).

Davidson says that *T. squamosa* is very common in the 'Craie chloritée of Rouen': it may be so, but in the middle of the 'Craie glauconieuse of St. Jouin' we find a form which is quite destitute of squamose ridges, and is ornamented with nearly straight but, slightly undulating, capilliform striæ. Except that it is of small size, it agrees more closely with d'Archiac's figures of *T. capillata* (Mém. Soc. géol. Fr. ser. 2, vol. ii.) than with the *T. capillata* of the Red Chalk figured by Davidson.

In this connexion we would recall the fact that *T. capillata* has been found by one of us in the Totternhoe Stone or 'Grey Bed' of Lincolnshire, and consequently well up in the Lower Chalk (see Quart. Journ. Geol. Soc. vol. xliv. p. 349). It has therefore a wider distribution in beds of Cenomanian age than in those of earlier epochs, and we are inclined to think that the Lower Greensand form figured by Davidson may have to be separated from it.

Lamellibranchiata.

Ostrea canaliculata, Sow. = O. lateralis, Nilss.

This is the *Chama canaliculata* of the 'Min. Conch.' vol. i. pl. 26. fig. 1 (1812), not the *Ostrea canaliculata* of a later volume (pl. 135. fig. 1).

The *Chama canaliculata* of Sowerby is the *Ostrea lateralis* of Nilsson (1827), as pointed out by d'Orbigny; and, having compared many French and English specimens, we agree in regarding them as the same shell, but Sowerby's name has the priority.

The shell which Sowerby called *Ostrea canaliculata* cannot bear that name, and, as it seems to be identical with the *O. lunata* of Nilsson, it should be so designated.

O. canaliculata (Sow., sp.) is a characteristic Cenomanian shell, and *O. lunata* belongs to the highest White Chalk of Trimingham and Mundesley.

Pecten interstriatus, Leym.

This name has frequently appeared in lists of Cretaceous fossils, and has been applied indiscriminately to Lower and Upper Cretaceous species. Leymerie, in 1842, gave the name to an Aptien species which is figured by d'Orbigny under that name in the 'Pal. Fr. Terr. Crét.' pl. 433. figs. 1–5, but in his 'Prodrome' (vol. ii. p. 169) he changed the name to *aptiensis*, because he found that *interstriatus* had been used for another species by Münster in 1841. The latter name, therefore, should not be used for any of the Cretaceous *Pectens*. The Lower Greensand species (*P. aptiensis*) has its own distinctive characters and does not range into Gault or Upper Greensand though it doubtless was the ancestor of the later interstriate *Pectens*.

PECTEN DUTEMPLEI, d'Orb., and PECTEN GALLIENNEI, d'Orb.

These are two of the species which have gone by the name of *interstriatus* in England. *P. Dutemplei* is described by d'Orbigny as having plain narrow ribs between the larger ornamented ribs, and as having its ears marked only by vertical lines of growth. *P. Galliennei* he describes as wanting the intermediate ribs and as having several strong radiating ribs on the buccal ear. The first is supposed to be confined to the Gault (Albien) and the second to the Cenomanian. We do not feel certain that the latter is more than a variety of the former, or that they are confined to separate stages. M. Bizet has sent us a specimen from the Cénomanien of Condrécieux which he calls *P. Galliennei*, though it has the intermediate ribs of *Dutemplei*. Specimens from La Hève, Warminster, and the Cenomanian of Devon do, however, agree better with *Galliennei*, and we have therefore so named them.

PECTEN PASSYI, d'Arch., Mém. Soc. géol. Fr. ser. 2, vol. ii. p. 309, pl. xv. fig. 9.

This is a fossil from the Tourtia of Tournay, and has a considerable resemblance to *P. Galliennei*, d'Orb., but is described as having perfectly straight, regular, and plain ribs, without any scales or nodulations. The interspaces are striated in the usual manner. Mr. C. J. A. Meÿer has specimens which possess these characters from his Bed 11, Dunscombe Cliff.

PECTEN SUBINTERSTRIATUS, d'Arch., Mém. Soc. géol. Fr. ser. 2, vol. ii. pl. xv. fig. 10.

Specimens which agree with the figure and description of d'Archiac occur in the Cenomanian of Devon. It is distinguished from the other interstriate species by its more numerous ribs, which are in low relief and are crossed by fine concentric lines of growth, each line where it crosses a rib developing a small short scale. These scales are much more numerous and much less prominent than those of *P. Galliennei*; they are most strongly marked on the anterior portion of the shell, and are mere slight ridges on the central ribs. The ears are plain or marked only by vertical lines of growth; the anterior ear is much larger than the posterior.

D'Archiac figures only a right valve, and, as Leymerie only figured a left valve of his *P. interstriatus*, d'Archiac cautiously remarks that his specimen may be only a right valve of that species. We have, however, a left valve which is clearly that of *subinterstriatus*, the only difference being that the ribs are rather fewer and placed at less regular intervals.

The *P. subinterstriatus* figured in Dixon's 'Geology of Sussex,' pl. xxviii. fig. 19, is wrongly so named, but is doubtless the *P. cretosus* of Defrance (non Goldf.), as stated on p. 386 of that work, this *P. cretosus* being probably the same as *P. nitidus*, Mantell.

PECTEN ELONGATUS, Lam.

There is much doubt about this species, because the figures given by d'Orbigny and Goldfuss are not alike, and because d'Orbigny's description does not agree with his figure. We take d'Orbigny's description as the best guide ('Pal. Fr.' p. 607), and from this we learn that it has 30 to 40 unequal ribs, sometimes alternating large and small ribs, sometimes grouped in threes (one large and two small ones), each having prominent lamellose scales at intervals. His figure, however, does not express these characters at all clearly. We have found specimens at La Hève which agree with his description exactly and are also identical with specimens from the Lower Chalk of England which we have been accustomed to regard as *P. elongatus*. In all of them there is a marked tendency for the ribs to be arranged in threes, a large one in the centre with a small one on each side.

Dr. Barrois states[1] that this species is identical with the form figured under the name of *P. cretosus* by Goldfuss ('Petr. Germ.' pl. xciv. fig. 2), and the figure certainly agrees with d'Orbigny's description. *P. elongatus* of Goldfuss is a Tertiary species.

It differs from *P. Marrotianus* in not having two minor ribs between each of the groups of three, in being much less regular, and in having much more prominent scales. We have not seen this species from the Cenomanian of Devon, though it ought to occur there.

PECTEN *cf.* PUZOSIANUS, Math. in d'Orb., 'Pal. Fr. Terr. Crét.' vol. iii. p. 610, pl. 437. figs. 1–4.

This is another case in which d'Orbigny's figure and description do not entirely agree. The figure shows perfectly plain ribs of unequal breadth, but set close together, interrupted only by concentric lines of growth; yet d'Orbigny says that the ribs are furnished on the sides with imbricated plates: he adds, however, that these plates are wanting in the middle of the shell, 'but may there have been abraded.'

We have specimens both from France and from Devon which much resemble the figure, except that their ribs are rather fewer, flatter, and more strongly marked, but there is no trace of their ever having borne imbricating plates; possibly these were very delicate and easily removed. From its occurrence in the typical Cenomanian country we think that this must be the shell described by d'Orbigny.

PECTEN SUBACUTUS, Lam. in d'Orb., 'Pal. Fr. Terr. Crét.' vol. iii. p. 605, pl. 435. figs. 5–10.

We had found a *Pecten* in the lowest part of the Devon Cenomanian which seemed to be this species, but its state of preservation

[1] 'Mém. sur le Terr. Crét. des Ardennes,' Ann. Soc. géol. du Nord, vol. v. (1878) p. 318.

was not good enough for certain identification. Fortunately, however, M. Bizet was so kind as to send us two specimens of *P. subacutus* from the Sarthe, and these enabled us to satisfy ourselves that the Devon species is the same. By the same means also Mr. Meyer has been able to identify a specimen in his collection. We have not seen it from any other locality, and it is another of the links which connect the Devon beds with the Cenomanian of the Sarthe.

PECTEN, sp.

A species occurs in the Cenomanian of France, and also in the highest greensand of Warminster, which we have not been able to identify. It bears a certain resemblance to *P. Raulinianus* of the Gault, and appears under that name in some lists, but the ornamentation is really very different. The shell bears a large number of narrow ribs, nearly straight, but of unequal size, smaller ribs being frequently, but not constantly, developed between those of normal size. Each rib bears a number of strong, triangular, spinous processes, arranged longitudinally, and projecting almost vertically upwards. Some of the smaller ribs bear similar but more slender spines, and some are nearly smooth. There are no striæ on the interspaces. The ears are not preserved on the few specimens that we have examined. We are not sure that it occurs in Devon, though some badly-preserved specimens resemble it.

LIMA SIMPLEX, d'Orb., 'Pal. Fr. Terr. Crét.' vol. iii. p. 545, pl. 418. figs. 5-7.

In the lower and most fossiliferous part of the Devon zone of *Ammonites Mantelli* there are several large, smooth species of *Lima*, and having obtained a specimen of *Lima simplex* from the Cenomanian of Vimoutiers, we find that one of the Devon species bears a close resemblance to it. It is large, compressed, and smooth over the greater part of the shell, but has a few narrow grooves on the anterior and posterior sides of each valve, which produce a sort of false ribbing on these portions of the shell.

LIMA HOPERI, d'Orb. (*non* Sow.), and LIMA CALYPSO, d'Orb.

D'Orbigny's figure of *Lima Hoperi* has led to some confusion, for it is certainly not the *Lima Hoperi* of Sowerby and Mantell, which is common in the Upper Chalk (Sénonien) of England, especially in the Margate Chalk. Assuming d'Orbigny's figure to be that of an adult specimen, it is much smaller, more compressed, and ornamented all over by shallow pitted grooves; whereas the true *L. Hoperi* is a large shell, more inflated, and smooth, except over narrow spaces on the anterior and posterior sides of each valve, which have a few faint grooves.

In the Cenomanian of Devon there is a *Lima* which somewhat resembles the shell figured by d'Orbigny as *L. Hoperi*, but it is more inflated, and has a deeper and more irregular set of pitted grooves over the greater part of the shell. This may be the *Lima*

Calypso of d'Orbigny, described in his 'Prodrome,' vol. ii. p. 167, as very near ('voisine') to *L. Hoperi*, but with more numerous punctated grooves, and occurring in the Cenomanian of Rouen.

CORBIS ROTUNDATA, d'Orb., 'Pal. Fr. Terr. Crét.' vol. iii. p. 113, pl. 280.

This is another shell, occurring in the Devon zone of *Ammonites Mantelli*, which the acquisition of French specimens has enabled us to identify. We should mention, however, that Mr. Meÿer has specimens which he had previously determined to be *C. rotundata*. It is common in the sandy facies of the Cénomanien at Vimoutiers, Gacé, and Mortagne, though the shell so often remains in the matrix that it is difficult to obtain more than casts of it; the same is the case in Devon, but a comparison of the casts leaves no doubt as to the identification.

ARCA LIGERIENSIS, d'Orb., 'Pal. Fr. Terr. Crét.' vol. iii. p. 227, pl. 317.

This is another common shell in the French Cenomanian which had been detected in the Devon beds by Mr. Meÿer. Having obtained several casts of it from Vimoutiers and elsewhere, we are also able to state that it is common in the hard rocky basement-bed of the Lower Chalk at Chard (commonly called 'Chloritic Marl').

TRIGONIA AFFINIS, Sow.

This species was at first regarded by Lycett as only a variety of *Tr. excentrica*, Park. (see 'Brit. Foss. Trigoniæ,' Pal. Soc. Monogr. p. 94), but in his Addenda (p. 187) he separates it again, and points out the characters by which it is distinguished. The only specimens which he refers to this species are one said to have come from Blackdown, now in the Jermyn Street Museum, one from Haldon (Mr. Vicary), and one in Mr. Meÿer's collection, from near Axmouth, which Mr. Meyer informs me came from his Bed 12, the upper part of our zone of *Ammonites Mantelli*. It is therefore a rare shell.

TRIGONIA DUNSCOMBENSIS, Lycett, 'Brit. Foss. Trig.' Pal. Soc. Monogr. p. 188, pl. xl. figs. 5, 6.

This species was entered in Mr. Meÿer's list of 1874 as 'sp. allied to *Tr. sinuata*, Park.,' and was described as a new species by Lycett in 1877. Mr. Meyer informs us that it occurs throughout the zone of *Ammonites Mantelli*, in his Beds 10, 11, and 12, at Dunscombe, Branscombe, Whitecliff, and Pinhay.

It is allied to *Tr. affinis* and *Tr. excentrica*, but though he distinguishes it from these, Lycett does not attempt to disentangle the foreign synonyms, neither does he record *Tr. dunscombensis* from any other localities. Under *Tr. excentrica* he gives the *Tr. sinuata*, Park., in d'Orbigny as a synonym, and notes that d'Orbigny records this *Tr. sinuata* from the lower beds of his Terrain Turonien (*i. e.* Cénomanien) at Le Mans, St. Calais, and Condrécieux in the Sarthe. We have not been able to obtain specimens of this *Tr. sinuata*, but

we think it is very likely to be *Tr. dunscombensis*, for we now know that the beds are of exactly the same age.

The true *Tr. sinuata* of Parkinson is only the young state of *Tr. excentrica*, Park., and Lycett states (p. 189) that there is no certain record of *Tr. excentrica* occurring in a higher position than the Blackdown Greensand. Mr. Meÿer tells us that he has *Tr. excentrica* from his Bed 2 (the horizon of the Cowstones of Lyme Regis), but that it does not occur in the zone of *Ammonites Mantelli*.

TRIGONIA DEBILIS, Lycett, 'Brit. Foss. Trig.' p. 189, pl. xl. fig. 8.

This is another species akin to *Tr. affinis*, but is at present only known from Bed 10 of Mr. Meÿer's notation at Dunscombe. Lycett thinks that it is the young of a much larger species, but states that it is quite distinct from the young of any of the known 'Greensand' species of *Trigoniæ glabræ*.

TRIGONIA CRENULATA, Lam. in d'Orb., 'Pal. Fr. Terr. Crét.' vol. iii. p. 151, pl. 295.

Mr. Meÿer has a specimen of this species from Bed 12, obtained from a block on the shore of Pinhay Bay, near Lyme Regis. It is said to be a common fossil in the Cenomanian of Vimoutiers and Gacé, as well as near Le Mans, but we only succeeded in getting casts of *Trigoniæ* which might belong to it, or to the next.

TRIGONIA CRENULIFERA, Lycett, 'Brit. Foss. Trig.' p. 189, pl. xl. figs. 1, 7, 9.

This was separated from *Tr. crenulata* by Lycett, the species being founded on specimens in Mr. Meyer's collection. They came from Beds 10 and 11. 'The chief distinction consists in the prominent zigzag costellæ upon the area and escutcheon,' and the median furrow of the area is a 'deeply impressed groove' (*op. cit.*).

TRIGONIA MEŸERI, Lycett, 'Brit. Foss. Trig.' p. 125, pl. xxiii. fig. 6.

A shell belonging to the *aliformis* group; it was referred to *Tr. abrupta*, Von Buch, by Mr. Meÿer in 1874, but Lycett gave good reasons for regarding it as a new species, and named it after its discoverer. It occurs in Beds 11 and 12 at Dunscombe and Pinhay, and has also been found in the fossiliferous basement-bed of the Chalk at Chardstock.

TRIGONIA VICARYANA, Lycett, 'Brit. Foss. Trig.' pp. 141 & 203, with figs. on pls. xxiii., xxv., xxviii., & xl.

Lycett fully discussed this species, which he distinguished from *Tr. Archiaciana*, d'Orb. (an Aptien species). He subsequently adopted Mr. Meÿer's opinion that *Tr. Archiaciana* does not occur in the Upper Greensand or Chloritic Marl of England, the Haldon specimens referred to that species belonging in reality to *Tr. Vicaryana*.

Both Meÿer and Lycett are inclined to regard the *Tr. spinosa* of

d'Orbigny, a common Cenomanian shell, as a synonym of this species. It is certainly not the true *Tr. spinosa* of Parkinson, and, having compared a specimen from the Chloritic Marl of Havre with d'Orbigny's figure of *Tr. spinosa* and with examples of *Tr. Vicaryana* from Devon, we believe them to be identical. *Tr. Vicaryana* is therefore a common shell on both sides of the Channel.

Cephalopoda.

AMMONITES COMPLANATUS, Mant. See Sharpe, 'Chalk Mollusca' Pal. Soc. Monogr. p. 19, pl. vii. figs. 1–3. = *A. Largilliertianus*, d'Orb., 'Pal. Fr. Terr. Crét.' pl. xcv.

Having found a specimen of this rare shell in a fallen mass of Bed 11 on Pinhay beach, west of Lyme Regis, it is interesting to observe that Sharpe identifies it with *A. Largilliertianus*, which has been found in the Cenomanian of Rouen, and also in that of the Sarthe, according to M. Guillier ('Géologie de la Sarthe,' 1886). M. Guillier apparently considers the two forms to be distinct species, for he enters both of them in his list. The original English specimen was found in the Chalk Marl of Hamsey, near Lewes.

AMMONITES EUOMPHALUS, Sharpe, 'Chalk Mollusca,' p. 31, pl. xiii. fig. 4.

This is another very rare ammonite, of which only one specimen was known to Mr. Sharpe, obtained from the base of the Chalk in Man of War Cove, Dorset. Our specimen was found in the sandy chalk, Bed 13 of Mr. Meÿer, in the cliff below Whitlands coast guard station, west of Lyme Regis.

AMMONITES GOUPILIANUS, d'Orb., 'Pal. Fr. Terr. Crét.' vol. iii. p. 317, pl. xciv. figs. 1–3; and Sharpe, 'Chalk Mollusca,' p. 38, pl. xvii. figs. 5 & 6.

This is a sharply-keeled ammonite, with faintly-marked sigmoid ribs, resembling *A. varians* in form, but distinguished by its suture. Mr. Meÿer has found one specimen in Bed 13 below Whitlands. Mr. Sharpe had only seen one obtained from the 'Grey Chalk' of Hamsey (? Chalk Marl). It has not been found in the Cénomanien of Western France, but occurs in beds of Turonian age at Saumur on the Loire.

AMMONITES LATICLAVIUS, Sharpe, 'Chalk Moll.' p. 31, pl. xiv. fig. 1.

This form was only known to Sharpe from the Chloritic Marl of the Isle of Wight, but it has since been found in the upper part of the Lower Chalk of Yorkshire (see Quart. Journ. Geol. Soc. vol. xliv. 1888, p. 351). Dr. Barrois has found it to be not uncommon in the zone which he calls by its name in the North-east of France, and which appears to be equivalent to our Chloritic Marl. In Devon, Mr. Meÿer has found a specimen in Bed 11.

AMMONITES OBTECTUS, Sharpe, 'Chalk Moll.' p. 20, pl. vii. fig. 4.

This is another peculiar ammonite described by Sharpe from a single specimen obtained by Mr. Wiest at Chardstock, and is one of the many species which occur at that locality and on the coast. The specimen found by Mr. Meÿer came from his Bed 11, Dunscombe, and this and one[1] from the 'Chalk with many Micrasters' of Dover are, so far as we know, the only others yet discovered.

AMMONITES RENEVIERI, Sharpe, 'Chalk Moll.' p. 44, pl. xx. fig. 2.

This is a rare Lower Chalk fossil found in the Isle of Wight and near Devizes, and also obtained by Guéranger in the Cenomanian of Le Mans, so that it is one of the species which links the Devon beds with the Lower Chalk, on the one hand, and with the typical French Cenomanian on the other. Mr. Meÿer found it in Bed 13 on a large fallen block below Whitlands, near Lyme Regis.

TURRILITES BECHII, Sharpe, 'Chalk Moll.' p. 66, pl. xxvi. fig. 13.

The original specimen of this was found near Lyme Regis by Sir H. De la Beche. Mr. Meÿer has obtained specimens from his Beds 12 and 13 (see list). At present it is known only from Devon.

AMMONITES (ACANTHOCERAS) PENTAGONUS, sp. nov. (Pl. V. figs. 1 & 1 *a*.)

This shell has some resemblance in general shape and curvature to the flattened forms of *Ammonites Mantelli*, but in the number and arrangement of its dorsal tubercles it resembles *A. Deverianus*, d'Orb.

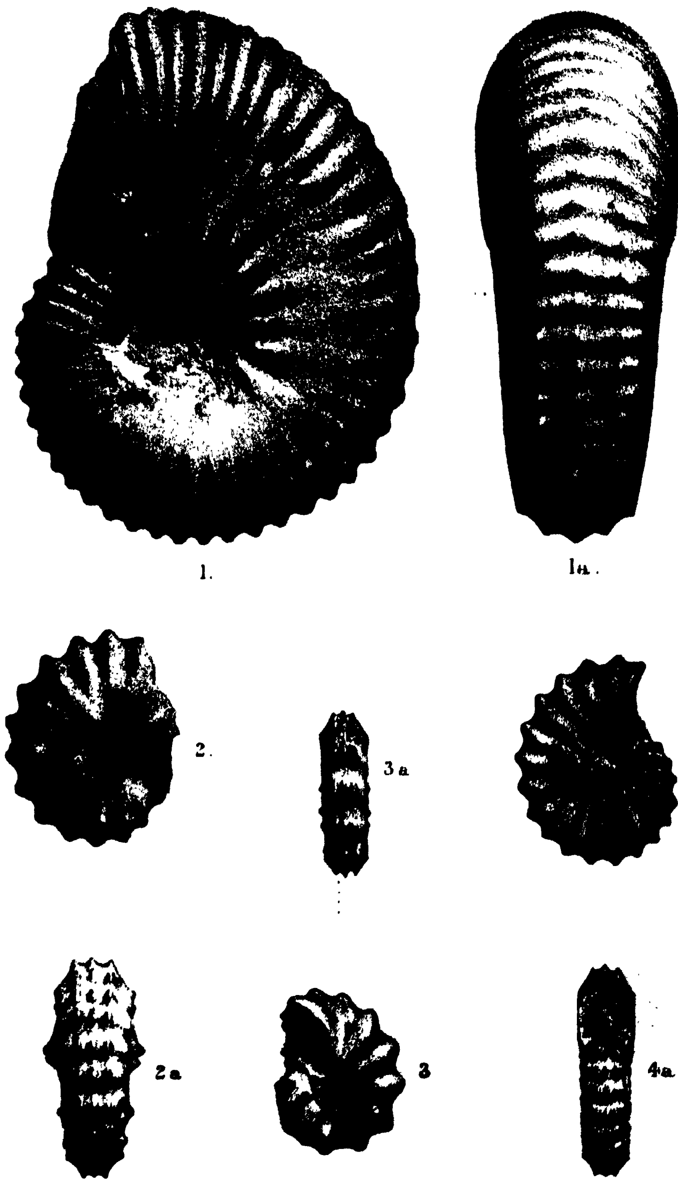
Only one specimen has been found, and this is figured in Pl. V. figs. 1 & 1*a*. Its dimensions are:—longest diameter 4 inches, shortest 3 inches; height of last whorl 1·8 inch, and width of mouth about 1·6 inch.

The whorls are about three parts involute, and the umbilicus is consequently small. The sides are flattened and the back rounded. A certain number of ribs, probably about 18, start from a set of tubercles, which surround the umbilicus, but on the sides other ribs come in, one or sometimes two between each of the first set, all becoming of nearly equal size and passing regularly over the back.

Each rib bears five equidistant tubercles, three on the back and one on each side of these, where the back curves to meet the sides. Thus, viewed from the back, five rows of tubercles are visible, the median row being the most prominent, and the two outer rows being the least elevated.

The ribs and tubercles are best developed in the younger part of the shell. In the body-chamber beyond the last sutural line some curious changes take place; for a space on the sides the ribs almost disappear, then the tubercles on the back become smaller, and near

[1] W. Hill on the Chalk of Dover, Quart. Journ. Geol. Soc. vol. xlii. (1886) p. 242.



F.H. Michael del et lith.

Mintern Bros. imp.

CENOMANIAN AMMONITES.

the mouth there is a set of strong, plain, rounded ribs without any tubercles, which pass over the back and along the sides till they nearly meet the ribs which start from the umbilical tubercles.

It is most nearly allied to *A. Deverianus*, but this species, as figured by d'Orbigny and Sharpe, differs in the following particulars: it is much less involute and more inflated than *A. pentagonus*, it has a much wider umbilicus, there is an extra row of tubercles along the middle of each side of the shell, and the median dorsal row is less prominent. Finally the ribs on the sides of the body-chamber break up into a number of large nodular tubercles.

The fossil now described is a phosphatic cast, and was found by one of us (A. J. J.-B.) in the glauconitic chalk (? Bed 13) above the zone of *Ammonites Mantelli*, in a fallen block at Humble Point, east of Charton Bay, near Lyme Regis. The name *pentagonus* refers to the pentagonal outline of the dorsal surface. It is doubtless a derived fossil and is associated with *A. hippocastanum*, *A. navicularis*, and *Scaphites æqualis*.

Ammonites (Acanthoceras) hippocastanum, Sharpe, var. compressus, nov. (Pl. V. figs. 2–4 *a*.)

The specimens to which we here draw attention may be regarded as a variety of the above species, but so different are they in general appearance that we were at first inclined to regard them as a distinct species. They do not, however, differ from *A. hippocastanum* more than some varieties of *A. varians* do from *A. Coupei*, and in both cases intermediate forms occur. Messrs. Sharman and Newton have kindly examined the specimens and concur in this view. But a form which departs so greatly from the figured type seems to merit description and illustration, especially as it is by no means uncommon on the Devon coast, in the layer of phosphatic nodules which are often cemented to the top of the *A. Mantelli*-zone (Bed 12), and in the overlying glauconitic chalk (Bed 13). It may be mentioned that the ordinary inflated form of *A. hippocastanum* is present in the same beds.

For the compressed form now described the varietal name of *compressus* is proposed. The dimensions of that figured in Pl. V. figs. 4 & 4 *a* are:—longest diameter 1·2 inch, lesser diameter about ·88 (seven-eighths) of an inch, width of the mouth about ·3 of an inch. The whorls are broad, the sides flattened, and the back elevated. About twenty tuberculated ribs pass over the back, but nearly half of these die away on the sides, converging to a row of ten or eleven tubercles which surround the umbilicus.

Viewed from the back, five rows of tubercles are visible, but the two outer rows are small and distant. The three inner rows are set close together along the back and are laterally compressed, so that the back is narrow and has a very different aspect from that of the typical *hippocastanum*, which further differs in having large and prominent lateral tubercles. Nevertheless varieties occur which seem to link this form with *hippocastanum*, and one of them is

figured in Pl. V. figs. 3 & 3*a*. This has only about thirteen ribs to the whorl, and only five umbilical tubercles; the whorls are narrow and less involute, all characters which bring it closer to the typical form, but the narrow back and flattened sides keep it under the variety *compressus*.

A third variety comes still closer to the *hippocastanum* of Sharpe, being more inflated and having more prominent lateral tubercles; the back, however, resembles the variety *compressus* in the close-set rows of elongate and laterally-compressed tubercles, so that its characters are distinctly intermediate between the two extreme forms. This is figured in Pl. V. figs. 2 & 2 *a*.

VII. Lists of Cenomanian Fossils found in Devon and in Normandy.

1. Fossils from the Cenomanian of Devon.

The following list represents the fauna of the beds that we have described in Devon, so far as it has been worked out. We have grouped them in three columns only, for the reasons stated on p. 142. The bed A of this list includes fossils obtained by Mr. Meyer in his Beds 10 and 11 from all localities except Beer Head, where we regard his 11 as part of 12. Bed B is the same as his Bed 12 plus the 11 of Beer Head only, Mr. Meyer having informed us which of his fossils came from the 11 of that locality. Bed C is Mr. Meyer's 13.

The fourth column shows how many of the fossils found in the Cenomanian group of the coast occur also at the base of the Chalk near Chard and Chardstock. This column is a nearly complete list of the Chard fauna, for there are very few of the fossils found there which do not also occur on the coast.

The last column indicates the species occurring in beds A, B, and C which are also found in the true Cenomanian of the North-west of France—*i. e.*, of the departments of the Seine Inférieure, Calvados, Orne, and Sarthe.

The letters by which the fossils are indicated in the first three columns have the following signification:—

S means: collected by ourselves or by Mr. Rhodes for the Geological Survey.

H means: identified by Dr. Hinde from specimens sent to him by ourselves.

M means: identified by Mr. Meyer from specimens in his own collection.

	Devon.			Chard and Chardstock.	N.W. of France.
	Bed A.	Bed B.	Bed C.		
Sponges.					
Elasmostoma consobrinum	H	...	...	...	*
,, sp.	H				
Trematocystia d'Orbignyi, Hinde	H	...	...	...	*
,, *siphonoides*, Mich.	H	...	...	...	*
Nematinion calyculatum	H				
,, sp.	H				
Hydrozoa.					
Porosphæra, sp.	H	...	...	...	* ?
? Genus (concentric layers)	H				
? Genus (tubular)	H				
Actinozoa.					
Micrabacia coronula, Goldf.	S M	...	S M	...	*
Thamnastræa, sp.	H				
Echinodermata.					
Caratomus rostratus, Ag.	S M	S M	S M	...	*
Catopygus columbarius, Lam.	S	M	...	*	*
Cidaris vesiculosa, Goldf. (test)	S	M	...	...	*
,, sp. (spines)	S				
Codiopsis doma, Desm.	...	M	...	...	*
Cottaldia Benettiæ, Kœnig	S M	M	...	...	*
Discoidea cylindrica, Lam.	...	S ?	S M	*	*
,, *Favrina*	S	S M	S	*	
,, *subucula*, Klein	S M	S M	S M	*	*
Echinobrissus lacunosus, Goldf.	...	M			
Echinoconus castaneus, Brongn.	S	M	S M	*	*
Echinocyphus difficilis, Ag.	...	...	M	*	
Glyphocyphus radiatus, Hœninghaus	...	...	M	*	*
Goniophorus lunulatus, Ag.	M	...	...	...	*
Hemiaster Morrisii, Forbes	...	M			
Holaster, sp.	S M	S			
Holaster lævis, Deluc	S M	M	S	*	
,, ,, var. *carinatus*, Ag.	S M	...	...	?	*
,, *suborbicularis*, Brongn.	M	...	...	...	*
,, *suborbicularis*, Wright	M	...	...	*	
,, *subglobosus*, Leske	S M	S M	? M	*	*
Holectypus bistriatus, Wright	...	M	...	*	
Pseudodiadema Benettiæ, Forbes	M	...	...	...	*
,, *Brongniarti* (?), Ag.	...	...	M	*	
,, *Michelini*, Ag.	...	M	M	...	*
,, *ornatum*, Goldf.	S	...	M	*	*
,, *variolare*, Brongn.	S M	...	S M	*	*
Pygurus lampas, De la Beche	M	...	...	...	*
Pyrina lævis, Ag.	S	...	M	...	*
,, *Desmoulinsii*, D'Arch.	...	M	...	*	*

TABLE (*continued*).

	Devon. Bed A.	Devon. Bed B.	Devon. Bed C.	Chard and Chardstock.	N.W. of France.
ECHINODERMATA (*cont.*).					
Pyrina ovulum (?), Ag.	M	M	...	*	
Salenia petalifera, Desm.	S M	M	...	*	*
,, ,, var. *gibba*, Ag.	...	M	...	...	*
,, *Clarkii* (?), Forbes	S	...	S		
Trematopygus ?, sp. nov.	...	M			
ANNELIDA.					
Ditrupa difformis, Lam.	...	S	M	*	*
Galeolaria plexus, Sow.	S	...	...	*	*
Vermicularia umbonata, Mant.	S				
CRUSTACEA.					
Callianassa, sp.	M	M			
POLYZOA.					
Eschara neustriaca, Mich.	H	...	...	...	*
,, sp.	H				
Ceriopora (sp. 12)	H	H			
,, (sp. 25)	H				
Reptomulticlausa papularis, Mich.	H	...	...	...	*
Ceriocava ramulosa, Mich.	H	...	...	...	*
Defrancia (*Pelagia*) *Eudesii*, Mich.	H	...	...	...	*
Micropora (sp. 4)	H	...	...	...	*
,, (sp. 5)	H	...	...	...	*
Radiopora (*Cellulipora*) *ornata*, d'Orb.	H	...	...	...	*
BRACHIOPODA.					
Crania cenomanensis (?), d'Orb.	...	M	...	*	*
Magas Geinitzi (?), Schloenb.	M				
Megerlia (*Kingena*) *lima*, Defr.	S	S M	M	...	*
Rhynchonella convexa, Sow.	S M	S M	M	*	*
,, *dimidiata*, Sow.	S M	S M	S M	*	*
,, ,, var. *gallina*, Brong.	S M	S	...	...	*
,, *Grasiana*, d'Orb.	S M	S M	M	...	*
,, *Cuvieri*, d'Orb.	...	...	S		
,, *Mantelliana* (?), Sow.	...	S	S		
,, *Schloenbachi*, Dav.	S M	M	...	...	*
,, *sigma*, Schloenb.	...	M			
,, *Wiestii*, Quenst.	...	S M	S M	*	
Terebratula arenosa, d'Arch.	...	M			
,, *arcuata*, Roem.	...	S M	...	*	*
,, *capillata*, d'Arch.	...	M	...	...	*
,, *obesa* (?), Sow.	...	M	...	...	*
,, *ovata*, Sow.	S	M	M	...	*
,, *semiglobosa*, Sow.	S	...	...	*	*
,, *squamosa*, Mant.	S	M	...	*	*

TABLE (*continued*).

	Devon. Bed A.	Devon. Bed B.	Devon. Bed C.	Chard and Chardstock.	N.W. of France.
BRACHIOPODA (*cont.*).					
Terebratula tornacensis, d'Arch.	...	M	...	...	*
,, *Verneuili*, d'Arch.	M	M			
Terebratella pectita, Sow.	S	M	...	...	*
,, *Menardi*, d'Orb.	S	M	...	*	*
Thecidium, sp.	M	M			
Trigonosemus incertus, Dav.	...	M	S M	*	
Terebrirostra lyra, Sow.	S	...	...	...	*
LAMELLIBRANCHIATA.					
Anomia, sp.	S	M			
Chama cornucopiae (?), d'Orb.	S	...	...	*	
Exogyra conica, Sow.	S	M	...	*	*
Inoceramus latus (?), d'Orb. (*non* Mant.)	S M	...	...	*	*
,, *striatus*, Sow.	S M	...	...	*	*
,, sp. (elongated)	S				
Lima (like *intermedia*, d'Orb.)	...	M	...	*	
,, *globosa*, Sow.	S	...	...	*	
,, *ornata*, d'Orb.	S M	M	M	*	*
,, *rapa*, d'Orb.	M	...	...	...	*
,, *rotomagensis*, d'Orb.	M	...	...	...	*
,, *semiornata*, d'Orb.	S M	M	...	...	*
,, *semisulcata*, d'Orb.	M	...	...	*	*
,, *simplex*, d'Orb.	S M	...	...	...	*
,, *tecta*, d'Orb.	M	...	...	...	*
,, sp. (with pitted grooves)	S	S	...	...	?
Lithodomus rugosus, d'Orb.	S M	...	...	*	*
Modiola (*Mytilus*) *divaricata*, d'Orb.	M	...	...	...	*
,, ,, *capitata* ?, Zittel	...	M			
,, ,, *Guerangeri*, d'Orb.	...	M	...	...	*
,, ,, *lineata*, Sow.	S	S M	S	*	*
,, ,, *ligeriensis*, d'Orb.	...	M	...	...	*
,, ,, *striatocostata*, d'Orb.	M	...	...	...	*
,, (? genus) *arcacea*, Gein.	M				
,, ,, *irregularis*, Gein.	...	M			
Janira aequicostata, Lam.	S	M	M	...	*
,, *quadricostata*, Lam.	...	...	...	...	*
,, *phaseola*, Lam.	...	M	M	...	*
,, *quinquecostata*, Sow.	S M	M	M	*	*
,, *decemcostata*, Münst.	M				
,, sp.	M				
Ostrea carinata, Sow. (*frons*, Park.)	S M	M	...	*	*
,, *hippopodium*, Nilss.	S M	M	...	...	*
,, *diluviana*, Linn.	S M	...	...	...	*
,, *vesicularis*, Lam.	S	...	...	*	*
Pecten asper, Lam.	S M	?	...	*	*
,, *acuminatus*, Gein.	M	M			
,, *elongatus* (?), Lam. (or new sp.)	S	...	...	...	*
,, *Galliennii*, d'Orb.	S	...	...	...	*
,, *orbicularis*, Sow.	S	...	...	...	*

TABLE (*continued*).

	Devon. Bed A.	Bed B.	Bed C.	Chard and Chardstock.	N.W. of France.
LAMELLIBRANCHIATA (*cont.*).					
Pecten Puzosianus, d'Orb.	S	M	...	...	*
„ *Passyi*, d'Arch.	M				
„ *rotomagensis*, d'Orb.	M	...	..	...	*
„ *subacutus*	S M	...	...	...	*
„ *subinterstriatus*, d'Arch.	S M	M			
Plicatula inflata, Sow.	...	...	S M	*	*
Spondylus Dutempleanus, d'Orb.	S	...	...	...	*
„ *Omalii*, d'Arch.	...	M			
„ *striatus*, Sow.	S	...	...	...	*
Anatina lanceolata, Gein.	M	S			
Arca Mailleana, d'Orb.	...	M	M	*	*
„ *Gallienii*, d'Orb.	...	M	...	...	*
„ *ligeriensis*, d'Orb.	S M	...	...	*	*
„ sp.	S				
Astarte cyprinoides, d'Arch.	M				
„ *Koninckii*, d'Arch.	M				
Cardita, sp. (cast)	...	...	S	*	
Cardium alternans, Reuss	M				
„ *alutaceum*, Goldf.	M				
„ *Mailleanum*, d'Orb.	...	M	...	...	*
„ *Hillanum*, Sow.	S	M	...	...	*
Corbis rotundata, d'Orb.	S M	...	...	*	*
Crassatella vindenensis, d'Orb.	...	M	...	...	*
„ *ligeriensis*, d'Orb.	...	M	...	...	*
Cucullæa, sp.	S				
Gastrochæna, sp.	S M				
Lucina turoniensis (?), d'Orb.	S	M	M	...	*
Opis, sp.	S M	...	...	*	
Pectunculus lens, Nilss.	M	...	...	* ?	
Solen æqualis, d'Orb.	M	...	...	...	*
Trigonia affinis, Sow.	S	M	...	*	*
„ *costigera*, Lyc.	M				
„ *crenulata*, Lam.	...	M	...	...	*
„ *crenulifera*, Lyc.	S M	...	...	?	
„ *debilis*, Lyc.	M				
„ *dunscombensis*, Lyc. (*sinuata*, d'Orb.)	M	M	...	...	*
„ *Meyeri*, Lyc.	S M	M	...	*	
„ *pennata*, Sow.	S M				
„ *scabra*, Lam.	M	...	...	...	*
„ *sulcataria*, Lam.	M	M	...	...	*
„ *Vicaryana*, Lyc. (*spinosa*, d'Orb.)	S M	S	...	*	*
Pholadomya æquivalvis, Goldf.	...	...	M		
Thetis Sowerbyi (?), Rœm.	...	...	S	...	*
Unicardium ringmeriense, Mant.	...	M	M	*	
Venus Goldfussi, Gein.	...	M			
GASTEROPODA.					
Aporrhais	S				
Avellana cassis, d'Orb.	...	S M	S	*	*

TABLE (*continued*).

	Devon. Bed A.	Devon. Bed B.	Devon. Bed C.	Chard and Chardstock.	N.W. of France.
GASTEROPODA (*cont.*).					
Avellana Prevosti, d'Arch.	...	...	M		
Columbellina, sp.	S	M	...	?	
Emarginula Meyeri, Gard.	...	M			
Fusus sp.	S M	S M			
Natica gaultina, d'Orb.	S	...	...	*	*
„ sp.	...	M			
Neritopsis	...	M			
Nerinea	M	...	...	?	
Pleurotomaria Cassissiana, d'Orb.	...	M	...	* several species	*
„ *Mailleana*, d'Orb.	M	M	...		*
„ cf. *gigantea*	S M	...	...		
„ *Rhodani*, P. & Roux	...	...	S		*
„ sp. 1	...	M	...		
„ sp. 2	...	M	..		
Pterodonta (several species)	M	...	...	*	
Rostellaria Mailleana, d'Orb.	M	.	...	...	*
Solarium ornatum, Sow.	...	M	...	*	
„ *Thirrianum* (?), d'Arch.	S				
Trochus girondinus, d'Orb.	...	M			
„ sp. (like *cirrus*, Woodw.)	...	M			
„ sp.	M	...	...	*	
Turbo Guerangeri, d'Orb.	...	M	...	...	*
„ (six other species)	...	M			
Turboidea, sp.	S	S			
Turritella Bauga, d'Orb.	M	...	...	...	*
„ sp.	M	...	...	*	
Voluta Guerangeri, d'Orb.	...	M	...	...	*
CEPHALOPODA.					
Belemnitella lanceolata, Sow. (non Schloth.) ...	S				
„ *plena*, Blainv.	...	...	S M	...	*
Nautilus Fittoni, Sharpe	S	M	S	*	
„ *expansus*, Sow	S	...	...	*	*
„ *Deslongchampsianus*, d'Orb.	...	...	M	*	*
„ *Fleuriausianus*, d'Orb.	...	M	...	*	*
„ *Largilliertianus*, d'Orb.	...	M	...	*	*
„ *lævigatus*, d'Orb.	...	S M	...	*	*
„ *subradiatus* (?), d'Orb.	S	...	...	...	*
Ammonites Austeni, Sharpe	...	S	...	...	*
„ *complanatus*, Mant.	S	...	...	...	*
„ *curvatus*, Mant.	S M	M	...	*	
„ *euomphalus*, Sharpe	...	...	S		
„ *falcatus*, Mant.	S M	M	...	...	*
„ *Goupilianus*, d'Orb.	...	...	M		
„ *hippocastanum*	...	...	S M	*	
„ *laticlavius*, Sharpe	M				
„ (?) *leptonema*, Sharpe	...	...	M		

TABLE (*continued*).

	Devon.			Chard and Chardstock.	N.W. of France.
	Bed A.	Bed B.	Bed C.		
Cephalopoda (*cont.*).					
Ammonites Mantelli, Sow.	S M	M	...	*	*
,, *navicularis*, Sow.	S M	M	S M	*	*
,, *pentagonus*, sp. nov.	...	...	S		
,, *planulatus*, Sow.	S	...	M	*	
,, *obtectus*, Sharpe	M	...	...	*	
,, *Renevieri*, Sharpe	...	...	M	...	*
,, *rotomagensis*, Defr.	...	M	S M	*	*
,, *varians*, Sow.	S	M	...	*	*
,, ,, var. *Coupei*, Brong.	S M	M	...	*	*
,, *Wiestii*, Sharpe (? = *dispar*, d'Orb.).	S	...	...	*	?
Scaphites æqualis, Sow.	S	S M	S M	*	*
,, ,, var. *obliquus*, Sow.	...	...	M	*	*
Turrilites Bechei, Sow.	...	M	M		
,, *costatus*, Lam.	S	M	...	*	*
,, *Gravesianus*, d'Orb.	...	M			
,, *Morrisii*, Sharpe	...	M	...	*	
,, *Scheuchzerianus*, Bosc	S	...	...	...	*
,, *tuberculatus*, Bosc	S	...	M	*	*
Hamites simplex (?), d'Orb.	S	...	M	...	*
Pisces.					
Lamna appendiculata (?), Ag.	S	...	S		
Ptychodus decurrens, Ag.	...	M			
Scapanorhynchus	S				
Oxyrhina Mantelli, Ag.	S				

From the above list it will be seen that the fauna of the Devon zone of *Ammonites Mantelli* is the fauna of the Cenomanian of the North-west of France. There are 10 species which are at present only known from their occurrence in these beds or near Chard. Deducting these from a total of 195 species and varieties of invertebrata, we have 185 which occur elsewhere, and out of these 132 are found to occur in the Cenomanian of Western France; while some others, such as *Echinocyphus difficilis*, *Magas Geinitzi*, *Ammonites planulatus*, *A. laticlavius*, *A. leptonema*, and *A. euomphalus*, etc., occur in beds of Cenomanian age elsewhere.

Moreover there are 4 echinoderms, 18 lamellibranchs, and 6 or more gasteropods which are not known to occur elsewhere in England, but which are common to this Devon deposit and the Cenomanian of Western France. Mr. Meyer's collection includes many species of gasteropoda which he has not been able to name, but we think it very probable that, if they could be compared with

specimens from the sands of the Sarthe, many of them would be found to agree with known Cenomanian species.

The Devon fauna has also a strong affinity with that of the Tourtia of Tournay, in Belgium. Several Tourtia species occur which have not yet been recorded from the Cenomanian of Western France. These are *Terebratula arenosa*, *T. Verneuilii*, *Pecten Passyi*, *P. subinterstriatus*, *Spondylus Omalii*, *Astarte cyprinoides*, *A. Koninckii*, *Avellana Prevosti*, and *Solarium Thirrianum* (?), nine species in all; besides two species which we have for the first time recognized in the Western Cenomanian, namely, *Terebratula capillata* and *T. tornacensis*.

In order to compare this Devon Cenomanian fauna with that of the Warminster Greensand it will be necessary to examine the chief collections of Warminster fossils, not only for the purpose of submitting many of the species to a critical examination, but in order to weed out of them all the specimens which are preserved in phosphate of lime, for these have really been obtained from the overlying Chloritic Marl and not from the green sand which lies between it and the Chert Beds. This investigation is not yet completed, but we are able to state that the Warminster Greensand contains comparatively few gasteropoda or cephalopoda, that *Ammonites Mantelli* and *A. navicularis* are rare shells in it, and that *Turrilites costatus* and *T. tuberculatus* do not occur.

It is true that many echinodermata, brachiopoda, and lamellibranchiata are common to the Devon and Warminster deposits, but these are shallow-water forms which would be likely to survive, and to be found in the shallow-water deposits of a slightly later date than that in which they first appear.

When the fauna found in Devon is compared with that of the Lower Chalk, say that of the Isle of Wight, we find a relationship of just the opposite kind. The *Nautili*, *Scaphites*, *Ammonites*, and *Turrilites* which are commonest in Devon are also those which abound in the Chloritic Marl and Chalk Marl of the Isle of Wight. Moreover, there are other species, such as *Ammonites Austeni*, *A. complanatus*, *A. euomphalus*, *A. Goupilianus*, *A. laticlavius*, *A. leptonema* (?), and *A. Renevieri*, which are much more rarely met with, but which have hitherto been found only in the Chalk Marl or in its basement-bed. When, however, we turn to the echinoderms, brachiopods, and lamellibranchs, we do not find so many of the Devon species in the Chalk Marl as in the Warminster Greensand; but, as no one doubts that the Chalk Marl was formed in a deeper sea than the Warminster Greensand, this absence of certain species is not to be wondered at.

We would remark that a mere percentage comparison of the faunas of two deposits is not of much value in determining their relative age, even when they occur within the same ancient province, unless there is good reason to suppose that they were formed in water of about the same depth. If, on the other hand, one is a deposit of shallower water than the other, the creatures which are most affected by the difference, such as sponges, polyzoa, brachiopoda, echino-

dermata, and all mollusca, except the cephalopoda, must be neglected in the comparison, and with reference to geological age only the cephalopoda should be admitted as evidence.

2. Fossils from the Cenomanian of Normandy.

The following list contains only the fossils obtained by ourselves at the places named, together with a few others for which we have the authority either of M. Lennier or M. Lecœur, and a few occurrences of particular echinodermata mentioned by Wright or in d'Orbigny's volumes.

A complete list of Cenomanian fossils, including those found in the Sarthe, would be a very long one, and would not serve any specially useful purpose. The present list may be taken to include all the commoner fossils of the more calcareous facies of the Cenomanian in North-western France, such species as would generally be met with by any collector. A full list of the fossils found in the Cenomanian of the Sarthe has been given by Guillier.[1]

For the identification of the sponges, polyzoa, and hydrozoa we are indebted to Dr. G. J. Hinde, F.G.S.; the other fossils have been determined by ourselves.

The first column contains all the fossils met with in the Cenomanian of the cliff-section near Havre, the second shows those found at and near Orbiquet, and the third those from Vimoutiers and Lisores. It should be mentioned that many in this third column are specimens given us by M. Lecœur. In these columns fossils examined and identified by ourselves are indicated by asterisks; those mentioned by others are indicated by letters—L standing for Lennier, Le for Lecœur, O for d'Orbigny, and W for Wright.

In order to compare this fauna with that of the Warminster Greensand on the one hand and the Lower Chalk on the other, we have indicated in the fourth and fifth columns the species which occur in these formations. By the Warminster Greensand we mean the sand lying between the Chert Beds of Warminster and the Chloritic Marl, and, so far as we can ascertain, 58 species out of 99 are common to the French Cenomanian and the Warminster Greensand, polyzoa being excluded.

The Lower Chalk of the fifth column is regarded as including the Chloritic Marl and the basement-beds of Dorset and Chard, but does not include the species which only occur in its representative on the Devon coast. Such species as only occur in the basement-beds are indicated by the letter B. Including these, 63 out of 99 species are common to the French Cenomanian and our Lower Chalk. Polyzoa are left out of account, because the Cretaceous species are greatly in need of revision, and it is uncertain what species range into the Lower Chalk.

It appears, therefore, that the percentage of Cenomanian species

[1] 'Géologie de la Sarthe,' Le Mans, 1886.

occurring in the Lower Chalk is a little larger than that occurring in the Warminster Greensand. We do not, however, rely greatly on this method of comparison; as already mentioned, it is to the cephalopoda alone that we look for reliable palæontological evidence regarding the age of such different deposits. Now the Cenomanian cephalopoda in our list number 14; of these only 7 occur at Warminster, while all of them occur in the Lower Chalk. Further, of those in the Warminster Greensand all except three (*Ammonites varians*, *A. Coupei*, and *A. falcatus*) are rare fossils, while in the Lower Chalk nearly all are very common. This evidence is very strongly in favour of the view for which we contend, and its force will be further alluded to in the sequel.

	Normandy.			England.	
	A	B	C	D	E
	La Hève and St. Jouin.	Near Orbiquet.	Vimoutiers and Lisores.	Warminster Greensand.	Lower Chalk.
Porifera (Sponges).					
Corynella rugosa, Hinde	*	...	...	*	
„ , sp.	*				
Elasmostoma consobrinum, d'Orb.	*	...	...	*	
„ *plicatum*, Hinde	*				
Trematocystis siphonioides, Mich.	*	...	...	*	
„ *d'Orbignyi*, Hinde	*	...	...	*	
Jerea, sp.	*				
Pachypoterion compactum, Hinde	*	...	...	*	
Plocoscyphia, sp. (fragments)	*	...	*		
Stauronema Carteri, Sollas	*	...	...	...	B
Hydrozoa.					
Porosphæra urceolata, Phil.	*	...	...	*	
„ sp.	*				
Actinozoa.					
Micrabacia coronula, Goldf.	*	...	...	*	*
Annelida.					
Ditrupa difformis, Lam.	*	...	...	*	*
Galeolaria filiformis, Sow.	...	*	...	*	*
„ *plexus*, Sow.	*	...	...	*	*
Crustacea.					
Scalpellum	*				

TABLE (*continued*).

	NORMANDY.			ENGLAND.	
	A	B	C	D	E
	La Hève and St. Jouin.	Near Orbiquet.	Vimoutiers and Lisores.	Warminster Greensand.	Lower Chalk.
ECHINODERMATA.					
Caratomus rostratus, Ag.	*	...	...	*	
Catopygus columbarius, Lam.	*	*	*	*	B
Cidaris vesiculosa, Goldf.	*	...	*	*	*
Cottaldia Benettiæ, Kœnig	*	...	*	*	
Discoidea subucula, Leske	*	*	*	*	*
Epiaster crassissimus, Defr.	*	*	*	*	*
Goniophorus lunulatus, Ag.	W	...	W	*	
,, , new sp.	*				
Glyphocyphus radiatus, Desor	*	...	Le		*
Hemiaster bufo, Desor	O	...	*		
Holaster carinatus (*lævis*)	*	*	...	*	*
,, *subglobosus*, Leske	*	...	...	*	*
Peltastes acanthoides, Ag.	O	...	O		
,, *clathratus*, Ag.	W	...	...	*	*
Pseudodiadema ornatum, Desor	*	...	*	*	*
,, *Benettiæ*, Forbes	*	...	...	*	B
,, *Normanniæ*, Cott.	...	...	W		
,, *Michelini*, Ag.	W	...	W	*	B
,, *variolare*, Ag.	*	*	*	*	*
Salenia Clarkii (?), Wright	*	...	...	...	*
,, *petalifera*, Ag.	*	...	...	*	B
,, *scutigera* (?), Gray	*				
POLYZOA.					
Alecto, sp	*				
Ceriopora (*Ceriocava*) *mammillaris*, d'Orb.	*				
Diastopora, sp. *a*	...	...	*		
,, sp. *b*.	*				
,, sp. *c*.	*				
Entalophora ramosissima, d'Orb.	...	...	*	*	
Heteropora, sp.	*				
Sparsicava irregularis, d'Orb.	*				
Melicertites compressa, d'Orb.	*				
Idmonea ramosa, Mich.	*				
Radiopora ornata, d'Orb.	*				
,, *tuberculata*, d'Orb.	*				
Micropora, 5 species	*				
,, 1 species	...	...	*		
Reptomulticlausa papularis, Mich.	...	...	*	*	
BRACHIOPODA.					
Megerlia (*Kingena*) *lima*, Defr.	*	...	*	*	*
Terebratella pectita, Sow.	*	...	...	*	B

TABLE (*continued*).

	NORMANDY.			ENGLAND	
	A	B	C	D	E
	La Hève and St. Jouin.	Near Orbiquet.	Vimoutiers and Lisores.	Warminster Greensand.	Lower Chalk.
BRACHIOPODA (*cont.*).					
Terebratella Menardi ?, Lam.	*				
Terebratula arcuata, Roem.	*	...	...	...	B
„ *biplicata*, Sow.	*	*	*	*	B
„ *capillata*, d'Arch.	*	...	...	...	*
„ *ovata*, Sow.	...	...	*	*	
Terebrirostra lyra, Sow.	L	...	...	*	
Rhynchonella convexa, Sow.	*	...	...	*	B
„ *dimidiata*, Sow.	*	...	*	*	B
„ *Grasiana*, d'Orb.	*	*	...	*	*
„ *Schloenbachi*, Dav.	*	*	*	...	?
„ *Lamarckiana*, d'Orb.	...	...	Le		
LAMELLIBRANCHIATA.					
Ostrea canaliculata, Sow. (= *O. lateralis*, Nills.).	*	*	*	*	*
„ *carinata*, Sow.	*	...	*	*	*
„ *hippopodium*, Nilss.	...	*			
„ *Lesueuri*, d'Orb.	L	...	...	*	*
„ *vesicularis*, Lam.	*	*	*	*	*
„ *vesiculosa* (var.)	...	*	*		
Exogyra conica, Sow.	*	*	*	*	*
„ *Rauliniana*, d'Orb.	*	*	*	*	*
Pecten asper, Lam.	*	*	*	*	B
„ *elongatus*, Lam.	*	...	...	...	*
„ *Galliennii*, d'Orb.	*	...	...	*	B
„ *orbicularis*, Sow.	...	...	*	*	*
„ *Puzosianus*, d'Orb.	*	...	...	*	
„ sp. 1	*	...	*	*	
„ sp. 2	...	...	*		
Janira quinquecostata, Sow.	*	*	...	*	*
„ *quadricostata*, Sow.	*	*			
„ *æquicostata*, d'Orb.	*	*	*	*	
Lima cenomanensis, d'Orb.	...	*	...	*	
„ *clypeiformis*, d'Orb.	L	*			
„ *simplex*, d'Orb.	...	...	*		
„ *semiornata*, d'Orb.	...	...	*	*	
Inoceramus striatus, Sow.	*	*	*	...	*
Spondylus striatus, Sow.	*	*	*	*	*
Mytilus ligeriensis, d'Orb.	...	*			
Trigonia spinosa, d'Orb. = *Vicaryana*	*	...	*	...	*
„ *crenulata*, Lam.	...	...	*		
Arca ligeriensis, d'Orb.	...	...	*	...	B
Corbis rotundata, d'Orb.	...	...	*	..	B
Cytherea plana ?, Sow.	...	...	*		

TABLE (*continued*).

	NORMANDY.			ENGLAND.	
	A	B	C	D	E
	La Hève and St. Jouin.	Near Orbiquet.	Vimoutiers and Lisores.	Warminster Greensand.	Lower Chalk.
LAMELLIBRANCHIATA. (*cont.*).					
Cytherea, sp. (small)	...	...	*	*	B
Cardium Hillanum, Sow.	...	...	*	...	B
Cyprina ligeriensis, d'Orb.	...	*	*		
GASTEROPODA.					
Avellana cassis, d'Orb.	*	...	*	...	*
Aporrhais, sp.	*				
Fusus Espaillaci, d'Orb.	...	...	Le		
Natica gaultina, d'Orb.	*	...	...	...	*
Pleurotomaria Archiaci, d'Orb.	L				
" *Mailleana*, d'Orb.	L	...	...	*	*
" *perspectiva*, Mant.	L	...	...	*	*
" sp.	*	...	Le		
Turboidea, sp.	*				
CEPHALOPODA.					
Ammonites varians, Sow.	*	*	*	*	*
" " var. *Coupei*, Brongn.	*	...	...	*	*
" *Mantelli*, Sow.	*	...	*	*	*
" *navicularis*, Mant.	*	...	...	*	*
" *falcatus*, Mant.	*	...	*	*	*
" *rotomagensis*, Brongn.	...	...	*	...	*
" *cenomanensis*, d'Arch.	...	...	*	...	*
Hamites simplex, d'Orb.	...	...	Le	...	*
" sp.	*				
Turrilites costatus, Lam.	*	...	*	...	*
" *tuberculatus*, Bosc	*	...	*	...	*
Baculites baculoides, d'Orb.	...	...	*	*	*
Scaphites æqualis, Sow.	*	...	*	...	*
Nautilus elegans, Sow.	...	...	Le	...	*
" *subradiatus*, d'Orb.	L	...	...	*	*

VIII. SUMMARY AND CONCLUSIONS.

It is now recognized by the Geological Survey of Great Britain hat the Gault and Upper Greensand can no longer be regarded as eparate stages or chronological divisions of the Cretaceous System. o speak of 'the Gault' as a formation distinct from and older than the Upper Greensand' is simply a mistake, for there can be no oubt that what is called Upper Gault in the East of England is

coeval with Upper Greensand in the west. They are merely different lithological facies of one group of deposits, and in the systematic classification of the future a new name will have to be found for this combined Gault-and-Greensand formation. It is much more developed in England than in France, and its name should be taken from some English locality.

On the other hand, we claim to have shown in this paper that when we pass from the Upper Greensand to the Lower Chalk we find that the change in the nature of the deposit corresponds with a great change in the fauna. This change is particularly conspicuous in Dorset and the Isle of Wight, where the base of the Chalk is always marked by the abundance of ammonites belonging to the species *varians*, *Coupei*, *curvatus*, and *Mantelli*, with *Turrilites tuberculatus* and *T. Morrisii*.

It is true that in Wiltshire there is a more gradual passage from Greensand to Chalk, and that some of these cephalopods do appear in the sand just below the Chloritic Marl, but this only shows that where the record is more complete we find a few forerunners of the Chalk Marl fauna coming in locally before the time when these species spread over the whole marine province.

We are, therefore, very decidedly of opinion that in England there is only one plane of division in this series of beds which can possibly be taken as separating one natural group of deposits from another. Further, seeing that England and Northern France formed part of one and the same area of deposition, we should be much surprised if a change of conditions which introduced a new assemblage of cephalopoda over the whole of Southern England did not show itself just as clearly in the North of France.

Before passing over to France, however, we described the sections to be seen in the cliffs of East Devon, where the Chalk Marl is represented by glauconitic and quartziferous limestones, rich in fossils and yielding an assemblage of species which more closely corresponds with the Cenomanian fauna of the Sarthe than with any other local English fauna. Moreover, the position of these beds is perfectly clear, for they are plainly marked off from the Upper Greensand, which is at the same time fully developed, and they are overlain by a complete Middle Chalk or Turonian stage. Here, therefore, on English ground we have a diminutive 'Cenomanian' deposit, part of which has an arenaceous character and a peculiar shallow-water fauna connecting it very closely with the typical Cenomanian of the Sarthe.

Our next study was that of the fine section exposed in the cliffs near Havre (Seine Inférieure). Our object was simply to see and decide for ourselves how much of it corresponded to the Gault-and-Greensand stage and how much to the Lower Chalk. We have indicated what seem to us the obvious and natural divisions of the series near Havre, and have pointed out that our interpretation of the section agrees closely with that of M. Lennier, who has studied and described it more carefully than any other French geologist.

The fact that the same bed is taken both by M. Lennier and by

ourselves as without doubt the base of the 'Cénomanien' is sufficient to prove that this base is a clearly-marked horizon. Now it seemed to us equally clear that this basement-bed corresponded to the Chloritic Marl of the Isle of Wight, or zone of *Stauronema Carteri*. The overlying beds are therefore the equivalent of our Chalk Marl, and the material of them is a chalky marl, though more visibly glauconitic than our Chalk Marl. At a certain level there is a bed which has some resemblance to Totternhoe Stone, and above this *Holaster subglobosus* becomes common, just as it does in some parts of England. About 80 feet from the base is a band of glauconitic chalk with phosphate-nodules, but there is no marked change of fauna here, and between 30 and 40 feet above this band we reach the base of the Turonian.

In our opinion, therefore, the acknowledged 'Cénomanien' of these cliffs is the equivalent of our Lower Chalk, and of that only. That its fauna should contain a certain admixture of species which lived in English waters at the very close of the Upper Greensand epoch can only surprise those who imagine that every portion of a contemporaneous set of beds must hold precisely the same fauna, whether one portion was formed in shallower water or not. The presence of *Pecten asper* and other fossils which do not occur in our Chalk Marl is capable of a very simple explanation, which we shall mention further on.

Beneath this 'Cénomanien' at Cape La Hève there is a representative of our Gault-and-Upper Greensand group. It is of no great thickness, only about 35 feet, unless the basal conglomerate or Carstone be added, as M. Lennier thinks it should, which would raise the total to 50 feet In this thickness, however, the Lower Gault (or Albien proper), together with so much of the Upper Greensand as is included in the zone of *Ammonites rostratus* (or Gaize), are clearly represented, but we do not think that any equivalent of the English zone of *Pecten asper* is present. This zone is so variable a quantity in England that there is nothing surprising in its being absent at Havre, where the whole Gault-and-Greensand group is evidently in process of thinning out.

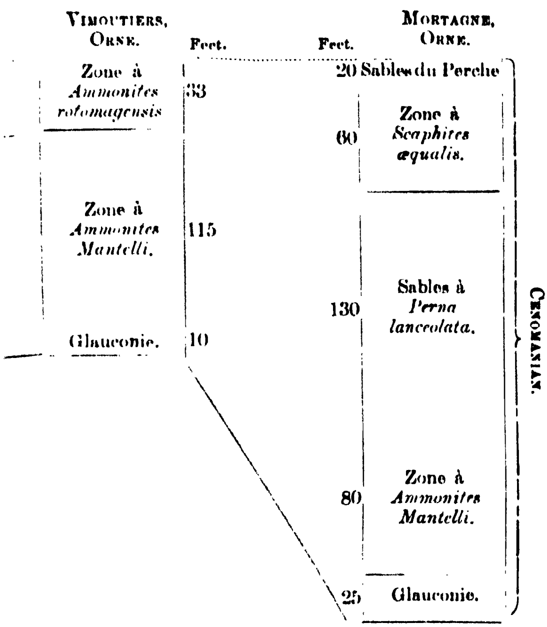
We have seen that on the south coast of England the zone of *Pecten asper* varies from 60 to about 6 feet, and north of Devizes, in Wiltshire, it thins rapidly till we get a sequence very like that near Havre, namely Chloritic Marl with phosphates resting on a few feet of unfossiliferous marly greensand which passes down into micaceous sandstone or Gaize. Moreover this zone is absent at Eastbourne, Folkestone, and Wissant, and also in Argonne and Perthois on the borders of the Marne and Meuse in the East of France, the Chloritic Marl in all these places resting directly on beds which are referred to the zone of *Ammonites rostratus*.[1]

Passing now to the Cenomanian of the Calvados and Orne, a section near Honfleur seems to show the Chloritic Marl with a somewhat different facies, for it no longer contains phosphatic nodules,

[1] See Barrois, 'Terr. Crét. des Ardennes,' Ann. Soc. géol. Nord, vol. v. (1878) p. 332.

[*To face* p. 172.

IONS.



but encloses large lumps or doggers of calcareous stone. From this point southward a similar bed or a layer of such glauconitic marly stone seems everywhere to form the base of the Cenomanian.

A section near Lisieux shows the Gault on the point of dying out, and beyond this place what we have called 'the Greensand' forms the base of the Cretaceous series. This is the 'Glauconie' of M. Paul Bizet, which in the east of the Orne may be 30 feet thick. We believe that the greater part of it corresponds to the Gaize of Havre, but the occurrence of *Pecten asper* in the upper part of it at Notre Dame de Courson, south of Lisieux, suggests the possibility of its also including a thin local representative of the *Pecten asper*-zone. At Vimoutiers, however, the thickness of this 'greensand' is small (only 10 feet), and the only fossil found is *Ostrea vesiculosa*, so that zonal subdivision becomes impossible. The important point is that it lies beneath the bed which we take to represent the Chloritic Marl, and consequently that it is of the age of our Upper Greensand.

At and south of Vimoutiers the Cenomanian proper is divided by French geologists into (1) zone of *Ammonites Mantelli* and (2) the 'Craie de Rouen,' or zone of *Ammonites rotomagensis*. There can be no doubt that these two zones are roughly equivalent to the lower and upper portions of the Cenomanian near Havre and Rouen, and here we are in complete agreement with French geologists.

Lithologically, however, there is a considerable difference between the Cenomanian of Vimoutiers and that of Havre; the lower part has ceased to be a 'craie glauconieuse,' and has become a fine glauconitic and slightly chalky sand, while the upper part has become a still less calcareous and more micaceous sand. Still farther south the lithological differences become more and more marked, till we arrive at the purely arenaceous type of Le Mans.

It is not suprising, therefore, to find that the fauna of these arenaceous beds differs considerably from that of our Lower Chalk and Chalk Marl; the physical and bathymetrical conditions under which these Cenomanian deposits were formed were evidently similar to those under which the highest part of our Upper Greensand was deposited, and hence many of our Upper Greensand molluscs and echinoderms continued to exist in these Cenomanian waters. Besides these, however, there is a certain number of species which are peculiar and do not occur either in our Upper Greensand or in the Chalk Marl, nor in the 'Craie glauconieuse' of Havre; but some of them do occur in the Cenomanian of Devon.

The beds which we have termed the 'Cenomanian of Devon' offer some special points of comparison with that of France, besides the striking resemblance between the two faunas. The minute structure of the bed numbered 11 by Mr. Meyer and of the upper and less arenaceous part of Bed 10 is similar to that of some beds in the lower part of the Cenomanian of Cape La Hève and of Vimoutiers (see p. 140).

Bed 13 of the Devon series has, however, no analogue in France, unless it is to be found in the famous fossiliferous bed near the top

of the Cenomanian at Rouen. We have not seen this bed, but it is described as a glauconitic chalk containing phosphatic nodules and many fossils, among which *Scaphites æqualis*, *Baculites baculoides*, *Ammonites navicularis*, and *A. rotomagensis* are common. It is remarkable that phosphatic fossils of these species abound in the bed which overlies No. 12 between Axmouth and Lyme Regis. Some of them are also common in Bed 7 of St. Jouin.

These facts suggest the idea that beds comparable to the upper part of the French Cenomanian, and, like it, containing many phosphatic nodules and casts of fossils, were originally deposited in the Devon area, but were afterwards destroyed by the action of currents, and nothing left of them except the hard phosphatic fossils, with grains of quartz and glauconite, to be embedded as *remanié* material in the beds which overlie the zone of *Ammonites Mantelli*.

Having thus summarized the opinions which we have been led to form from an examination of the rocks and their contents in the West of England and France, we shall conclude by discussing the view which is generally held in the latter country regarding the correlation of the several parts of the two series.

It is on the Cenomanian of Havre that we must concentrate our attention, because when its relative age is settled that of the inland departments will follow as a matter of course. No one now is likely to recur to the view of Prof. Hébert that the Cenomanian sands of the Sarthe are newer than the Craie de Rouen, and that no representative of them exists in Normandy or England.

The view current at the present time among French geologists is that the lower part of the Cenomanian of Havre, as defined by M. Lennier and ourselves, corresponds with the upper part of our Upper Greensand—with so much of it, in fact, as is included by Dr. Barrois in his zone of *Pecten asper*. We cannot find, however, that anyone has yet attempted to indicate how much of the Craie glauconieuse is equivalent to the English Lower Chalk and how much to the zone of *P. asper*.

It is true that Dr. Barrois has expressed his belief that his zone of *Ammonites laticlavius* (our Chloritic Marl) in the East of France corresponds with 'le banc Rotomagien classique de Rouen,'[1] but in answer to our enquiries he informs us that he has no personal acquaintance with the Havre or Rouen sections; that the fossils mentioned in his note were collected for him, and were said to come from the 'Craie de Rouen'; that he had no assurance that they came from Rouen itself; that some of them are preserved in whitish phosphate and some in glauconitic material, and that they may be 'un mélange.' This being so, it is quite possible, as he admits, that some of them were obtained on the coast, and may have come from the very bed which we identify with the Chloritic Marl; in any case, we feel sure that if Dr. Barrois had visited Havre after his

[1] 'Mém. sur le Terr. Crét. des Ardennes,' Ann. Soc. géol. Nord, vol. v. (1878)

prolonged study of the Cretaceous rocks of England he would have arrived at the same conclusion as we have.

It is indeed much to be regretted that Dr. Barrois did not carry out his intention of visiting Normandy, for there is no other Frenchman who has so extensive a knowledge of the Upper Cretaceous series in England and France. It would appear that the French have not yet indicated the place of the Craie de Rouen in the coast-section; that is to say, they have not divided this section into a zone of *Ammonites rotomagensis* and a zone of *A. Mantelli*, as at Vimoutiers. As regards its correlation with English sections, the French view rests apparently on three points of similarity between their 'Craie glauconieuse' and our Upper Greensand, such as would naturally strike any one who knew the English Chalk and Greensand only from published descriptions; these are:—

(1) The large amount of glauconite in the Cénomanien.
(2) The occurrence of frequent layers of chert.
(3) The presence of *Pecten asper* and other fossils common in the 'Warminster Greensand.'

We will take these points *seriatim*. (1) It is a mistake to suppose that the material of the 'Craie glauconieuse' resembles that of our Greensand. The very use of the word 'Craie' indicates the difference, and is quite correct in the department of Seine Inférieure, where the matrix does consist of fine chalky matter. Our Upper Greensand, on the contrary, is a sand consisting of quartz and glauconite, though it is sometimes cemented by calcite into a calcareous sandstone.

(2) The occurrence of layers and lumps of true chert does undoubtedly create a superficial resemblance between the two sets of strata; but the researches of Dr. Hinde have so completely proved the connexion between the formation of cherts and the existence of siliceous sponges, that the mere occurrence of cherts can only be taken as evidence of the conditions being locally favourable to the growth of such sponges.

(3) The presence of *Pecten asper* and other fossils, which in England are chiefly found in the Upper Greensand, is the sole argument that requires serious consideration. Let us first of all see what it amounts to when admitted without any qualification. Where does this special fauna exist in England? Certainly not in the Chert Beds either of Wiltshire, Dorset, or the Isle of Wight, which have everywhere a very limited fauna. What are usually called 'the fossils of the Warminster Greensand' have mostly been obtained from a bed of bright green sand (about 10 feet thick) lying above the Chert Beds, and passing up into Chloritic Marl with phosphate-nodules and *Stauronema Carteri*. It is only here, just below the base of the Chalk, that the Chalk Marl cephalopoda make their first appearance in England, and are associated with *Pecten asper* and other fossils which very shortly disappeared from the English part of the Cretaceous sea. It is quite a mistake to suppose that this is a typical Upper Greensand fauna; it is only that of the

very highest bed, so that if two thirds of the French Cenomanian are to be correlated with the thin bed of Greensand near Warminster on the strength of the similarity between the faunas, we must imagine that this thin bed has expanded to a thickness of 80 feet or more in France, although the beds both above and below have very greatly diminished in thickness.

Our lists, however, show that, of the fossils which may be collected from these beds at Havre in a few days' time, quite as many occur in our Chalk Marl as in the Warminster Beds. We suspect that the occurrence of *Pecten asper* has influenced the French systematists more than any other element in the fauna; but our experience in England has convinced us that *P. asper* is very sporadic in its mode of occurrence, and required a very special kind of environment.

We consider it very unsafe to trust to echinoderms or ground-feeding molluscs in correlating at so great a distance apart formations of different lithological character, because the conditions of life may also have been different in the two areas. One condition alone, namely, greater depth of water, might be sufficient to exclude from the one formation species which found a suitable location in the other area. This, we think, is the reason why *Pecten asper* and many other of the Warminster molluscs and echinoderms do not occur in the Chalk Marl, not because they had everywhere ceased to exist, but simply because the water was too deep for them.

The case is quite different with the cephalopoda, for they could move freely from place to place, and were not directly dependent on depth of water or on the nature of the sea-floor. They must therefore be much more trustworthy chronological guides; and if we rely upon their guidance in the present case, we find that they lead us to the very conclusion which we regard as correct, for the cephalopoda of the lower part of the Cenomanian of Havre are identical with those of our Chloritic Marl and Chalk Marl, and they do not occur in the Chert Beds of our Upper Greensand.

Let us now take another point of departure, and consider what modifications are likely to present themselves in our Chalk Marl when traced into shallower water and nearer to a line of coast. If we examine the Chalk Marl of the Isle of Wight under the microscope, we find that it actually is a C r a i e g l a u c o n i e u s e; it consists essentially of minute grains of quartz and glauconite, and of shell-fragments embedded in a fine chalky matrix. The material of the corresponding part of the Cenomanian at Havre has less of the chalky matrix, and a larger proportion of the inorganic materials (quartz and glauconite).

There is, in fact, just the difference that one would expect to find in a contemporaneous deposit accumulated rather nearer to the land, and we have shown that this change gradually increases till the chalky ingredient disappears entirely, and we reach shallow-water sands and sandstones. Would it not be surprising if there were not a corresponding change in the fauna? Is it likely that the same assemblage of fossils would inhabit the littoral sandy floors, the

intermediate depths where glauconitic marls and sands were accumulating, and the comparatively deep water of the Chalk Marl area?

Further, as the period was one of continued subsidence, and as the formation of the Chalk Marl was preceded by that of glauconitic sand in a shallower sea, what is more likely than that the creatures which lived in the shallower sea should gradually migrate to other tracts where the same conditions prevailed, as the area of the sea grew larger, and the central portion of it grew deeper?

Expressed in a few words, our belief is that the 'Cénomanien' of Havre and Rouen is simply a southern extension of our Lower Chalk, formed in a somewhat shallower part of the sea, rather nearer to a coast-line, and in a locality where conditions were more favourable to the growth of siliceous sponges. Hence it consists of a rather more sandy and glauconitic chalk, with a larger amount of siliceous matter in the form of sponge-spicules and chert-nodules.

We would point out that English geologists have hitherto been obliged to accept the idea of a 'Cénomanien' which could not be correlated with any one or two divisions of the English Cretaceous series, but was supposed to include a *Pecten asper*-zone which, in England at any rate, had no definite base. Our enquiry relieves them from the necessity of adopting so unsatisfactory a correlation, and substitutes a Cenomanian with a clearly-defined base both in England and France.

As regards what has been termed 'the zone of *Pecten asper*' in England, we think that some other fossil should be chosen as an index of the zone, so as to avoid the confusion which has arisen from the presence of *Pecten asper* at higher horizons in France. Unfortunately cephalopoda are so rare in this zone that it is impossible to select one of that class, and we think that it is best to leave the matter for future consideration.

PLATE V.

Cenomanian Ammonites. For Explanation, see text, pp. 156, 157.

DISCUSSION.

The PRESIDENT said that any attempt such as the Authors of the present paper have made to correlate any part of the Cretaceous beds of this country with those of the Continent must be hailed with satisfaction by all students of geology; and as the present Authors have given especial attention to this subject, their views deserve the most careful attention from geologists. He invited discussion on the paper that they had just heard read, and asked Mr. Hill whether the floating cephalopoda referred to by him included tetrabranchiata, or were confined to dibranchiata.

Dr. W. F. HUME, in congratulating the Authors on the paper, expressed himself in complete agreement with their conclusions, and remarked on the extreme variation in thickness displayed by the Cenomanian beds exposed in Beer Bay and Hooken Cliff respectively. He also asked whether the Authors would consider the

Chloritic Marl to the westward as younger than the easterly exposures of the same.

Mr. STRAHAN remarked that he was under a disadvantage in discussing the paper, through not having seen the Continental sections referred to. It seemed, however, to be clear that English geologists were having reason to repent the introduction of Continental names into their Cretaceous nomenclature. He himself had always hesitated in using the term 'Cenomanian' from a doubt as to its precise application in this country. The correlation was most important, for the principal break in our Secondary rocks occurs at the base of the Upper Cretaceous group. He enquired if a 'Carstone' and yellow sand which intervened between the Gault and Kimmeridge Clay at Cape La Hève were not the same as the ferruginous grit which forms the base of the Gault in Dorset and elsewhere. Phosphatic nodules occur in the Chloritic Marl and sporadically through the Upper Greensand, and seem to be foreign to the matrix in which they are embedded. The glauconitic grains, too, seem unlikely to have been formed in the water which distributed the sands and coarse grits. He asked the Authors whether they had any clue to the deposits with which these materials had originally been associated. In referring to Mr. Hill's Continental investigations, he congratulated him on a fine piece of work.

Dr. J. W. GREGORY congratulated the Authors on the value of the paper and the greater precision that they have given to a useful term. The confusion in regard to the term 'Cenomanian' is not so much a case of hasty use of a foreign name in England, as of unsatisfactory original definition of the term abroad. He fully agreed with the Authors that echinoids are rather a clue to conditions of formation of a deposit than evidence as to its exact contemporaneity in age.

Mr. R. S. HERRIES hoped that, as a result of this paper, geologists would use the term 'Lower Chalk' in place of 'Cenomanian,' at any rate when speaking of the English beds here described.

Mr. W. HILL, in reply to the President, remarked that they relied on the occurrence of tetrabranchiate cephalopoda to prove the age of the beds, rather than on the fauna which must have existed entirely on the sea-bottom. He thought that the Chloritic Marl of the eastern sections was probably older than that more to the westward. Beds 10, 11, and 12 were certainly seen as far as Branscombe Cliff. He believed that the phosphatized fossils, which Mr. Strahan suggested were derived, were not necessarily so, but might be of the same age as the bed containing them. There were but few phosphatized fossils in the Chloritic Marl of La Hève; and the fact that this marl contained small quartz-pebbles and much sand seemed to him evidence of current-action. He was prepared to admit that the Carstone-like bed seen in the cliffs at Cape La Hève might be of Gault age, and, in conclusion, heartily thanked the Fellows of the Society, on behalf of Mr. Jukes-Browne and himself, for their cordial reception of the paper.

8. *On the* SPEETON SERIES *in* YORKSHIRE *and* LINCOLNSHIRE. By G. W. LAMPLUGH, Esq., F.G.S., of H.M. Geological Survey. (Read January 22nd, 1896.)

CONTENTS.

I. INTRODUCTION.

IN describing the clays which underlie the Chalk at Speeton on the Yorkshire coast in a paper communicated to this Society in 1889,[1] I attempted to show the necessity for a fresh classification of these deposits. Further investigation of this section has fully confirmed the views then advanced. It has also indicated the desirability of a corresponding revision of the inland exposures of the rocks of the same age in Yorkshire and Lincolnshire, since it is only by means of the knowledge of the full sequence to be acquired on the coast-section that the true relationship of the limited and isolated exposures of the interior can be unravelled.

Using such opportunities as have at intervals occurred, I have therefore more or less closely examined the base of the Chalk escarpment throughout its whole length in Yorkshire and Lincolnshire, and desire in this paper to put on record the result of my investigation. It will be shown that the divisions proposed for the Speeton section are readily applicable to the inland exposures, and indeed afford the most convenient and natural means of palæontological classification, albeit some modification of the systems usually applied is thereby required.

It may be well at once to state that, while my chief aim will be to establish the correlation of the deposits by means of their palæontology, no attempt will, for the present, be made to carry the palæontological research further than is necessary for this purpose. Hence the fossils dealt with herein will only partially represent

[1] 'On the Subdivisions of the Speeton Clay,' Quart. Journ. Geol. Soc. vol. xlv. pp. 575–618.

the fauna of the various deposits. With the material already collected it would indeed have been possible to present much ampler lists. But the mischief done by the publication of swollen catalogues of hasty determinations, not in these deposits alone, but throughout the whole range of the Secondary rocks, has been so great, and the precise recognition of many of the forms in the present state of their nomenclature is so difficult, that I have thought it advisable to restrict myself as far as possible to the use of those few species which have been adequately described and figured rather than risk adding to the existing confusion.

That the fauna of these rocks has been hitherto much neglected by British palæontologists is no doubt mainly due to the fact that, so far as the British Islands are concerned, it is comparatively restricted both in its occurrence and its interest, the fossils of these marine deposits affording no ready points for comparison with those of the equivalent freshwater strata of the south of England. Over large areas of the continent of Europe, however, as was so clearly shown 25 years ago by Prof. Judd,[1] the conditions of deposit are more directly comparable, and there is a close relationship in the fauna. Recently Prof. A. Pavlow[2] has made a very careful study of the cephalopoda of these rocks with this relationship in view, and his monograph for this branch of the fauna affords a secure basis from which to discuss many questions of stratigraphy and correlation. But not until the rest of the fauna has been taken in hand, and in like manner studied and compared with that of the Continental equivalents of these deposits, will it be possible to compile satisfactory lists of the fossils, or to consider to full advantage the broader aspects of the subject.

II. Further Notes on the Speeton Section.

In my former paper I proposed to divide the clays of the Speeton section into zones by means of the belemnites, which are by far the most abundant and the most characteristic fossils contained in the deposit.[3] Prof. Pavlow has since shown that each type of belemnite selected for this purpose may be considered palæontologically as a group of allied forms presenting variations of specific value. These variations will no doubt in some cases enable us to trace out minor zones.

[1] 'Additional Observations on the Neocomian Strata of Yorkshire and Lincolnshire, etc.,' Quart. Journ. Geol. Soc. vol. xxvi. (1870) pp. 326–348.

[2] 'Argiles de Speeton et leurs Équivalents,' Bull. Soc. Imp. d. Naturalistes de Moscou. n. s. vol. v. pp. 181 & 455 (1891–92). (Also published separately, Moscow, 1892.)

[3] At that time some objection was raised to my selection of the belemnites as the zonal fossils; but, as I then stated, it was quite evident that no other fossils would serve the purpose so well, and I am pleased to find that this statement has been fully borne out and justified by further investigations. As Pavlow has shown, the study of the belemnite-fauna of the epoch is prolific in results throughout Europe. Prof. Dames, in a recent paper, 'Ueber die Gliederung der Flötzformationen Helgolands,' states for that island 'hier wie dort sind die Belemniten die leitenden Fossilien,' Sitzungsber. k. preuss. Akad. Wissensch. Berlin, vol. i. (1893) p. 1031.

Thus *Belemnites pistillirostris* and *B. cristatus* are together more restricted in their range than *B. jaculum*, to which they are closely allied; while *B. Jasikowi* and *B. obtusirostris* similarly occupy a portion only of the zone of *B. brunsvicensis*.

As several of the forms, however, seem to occur indiscriminately throughout the realm of the allied species, I think that for stratigraphical employment, as distinct from their more strictly palæontological study, it will be found serviceable to retain for our present purpose the broader system of nomenclature. It must therefore be understood that in the stratigraphical notes in the following pages the specific names of the zonal belemnites, and to a less extent of the zonal ammonites also, will be freely used in this broader sense, embracing all the closely-allied variations.

Since 1889 I have several times had opportunities for examining exposures of the strata on the foreshore at Speeton, and have been enabled thereby to collect much new palæontological material, and to fix the horizon of a few forms whose exact position had been doubtful. These results, as regards the cephalopoda, are summarized in the Table facing p. 184, where the species as determined by Prof. Pavlow are arranged according to their stratigraphical position.

[On revisiting Speeton while this paper was in the press I had the good fortune to find in the uppermost part of the section, of which our knowledge is still incomplete, among the recent slips under the Chalk escarpment 450 yards south of Speeton Gap, a small strip of brown marly clay, 2 or 3 feet thick, which contained belemnites of a type that I had not hitherto seen at Speeton. In structure, size, and outline this form shows close affinities to *Belemnites jaculum*, but differs markedly from that species in the character of the alveolar extremity: most of the specimens possess a slight lateral groove in the subalveolar region. It seems very probable that this may be the form recorded from Heligoland by Prof. Dames (*op. jam cit.*) as *B. fusiformis*, Voltz, which in that island occupies a zone between the beds with *B. minimus* and those with *B. brunsvicensis*.

I could find no other fossils along with this belemnite, and the band which contained it was bounded on all sides by slips; but below the brown clay was a mass of black pyritous clay with *Ammonites Deshayesii*, and above it dull black clay without fossils such as I have elsewhere seen to occur beneath the marls (A) with *B. minimus*, and there is much likelihood that the slips have preserved the true sequence of the beds.—April 22nd, 1896.]

The reiterated[1] contention of the Rev. J. F. Blake[2] that 'Portlandian' beds may after all exist, as supposed by Prof. Judd,

[1] 'Annals of British Geology for 1892' (London, 1893), Introductory Review, p. xviii.

[2] 'Geology of the Country between Redcar and Bridlington,' Proc. Geol. Assoc. vol. xii. (1891) p. 115.

between the lower Coprolite Bed (E) and the Bituminous Shales (F) of my published section, though it has already been once answered,[1] must here be referred to. The contention is based on a misapprehension of the valuable section published by Leckenby in 1859,[2] for it is beyond doubt that the Bituminous Shales (F of my former paper) are the same strata as the 'Beds Nos. 4 and 5' of Leckenby's section which Blake suggests I may not yet have seen.

These shales have been frequently exposed at Speeton both before and since the publication of my account of the section, and I have carefully examined them to a greater depth than my measurements indicated, since (as stated in my previous paper) the folds into which they are locally thrown, and their position near low-water mark on the foreshore, render detailed work on their lower portion very difficult.

The only beds described by Leckenby that I have not yet had an opportunity of examining are those still lower strata to which he applies the numbers 1, 2, and 3, and assigns a thickness of 30 to 40 feet. The fauna is apparently rather better preserved in these beds than in the compressed shales above, and is of undoubted Kimeridgian age, including *Ammonites (Perisphinctes) biplex*; *A. (Hoplites) eudoxus* =*A. evalidus*, Bean MS.; a form near *A. alternans*, labelled *A. Kapfii*, Opp., in some collections; and *Belemnites Troslayanus*, d'Orb.

Specimens from this horizon occur in all the old collections preserved in our public museums, but the only examples that I have myself obtained have been from nodules washed up on the beach. Mr. R. S. Herries, however, has been more fortunate, having some years ago found an exposure of the strata on the foreshore north of Speeton from which he was able to collect all the above-mentioned species, and I have to thank him for his kindness in so readily placing these, with other specimens from his extensive collection, at my disposal. The same horizon seems, as will presently be shown, formerly to have been exposed in one of the clay-pits at Knapton, 14 miles inland.

Our knowledge of the lowermost portion of the Speeton section, below the top of the Upper Kimeridge Shales, must therefore still rest on Leckenby's meagre but probably quite accurate description. I have before pointed out that the so-called 'Middle Kimeridge' and 'Lower Kimeridge' mentioned by Prof. Judd[3] and others[4] as occurring in Filey Bay seem, as now admitted by Blake,[5] to consist entirely of glacially-transported masses of shale, chiefly of Lower Lias age, such as characterize the drift-deposits of this part of the coast.

A well-boring sunk by the Filey Waterworks Company in a field adjoining the railway-station at Filey, after passing through 190 feet

[1] 'Argiles de Speeton,' *op. cit.* 1re partie, p. 210; sep. cop. p. 30.
[2] 'Geologist,' vol. ii. p. 9.
[3] 'On the Speeton Clay,' Quart. Journ. Geol. Soc. vol. xxiv. (1868) p. 240.
[4] J. F. Blake, Quart. Journ. Geol. Soc. vol. xxxi. (1875) p. 211.
[5] 'Excursion to the East Coast of Yorkshire,' Proc. Geol. Assoc. vol. xii. (1891) p. 213.

of drift,[1] further penetrated pale-blue sandy clay or shale for 75½ feet before reaching the water-bearing Coralline Oolite. This shale evidently represents the lowest Kimeridgian beds; the only fossil that I was able to obtain from it was an indeterminable fragment of a small slender belemnite, distinct from any of the Speeton species known to me.

In my former paper I described the strikingly sudden change of fauna which takes place at the top of the zone of *Belemnites lateralis*. Immediately below this horizon the prevalent ammonites are the deep-whorled, round-backed forms of the genus *Olcostephanus* and its allies, and the belemnites all belong to the short thick *lateralis*-group, while immediately above it the clays abound in the flat-whorled, square-backed ammonites of the genus *Hoplites* and the slender hastate belemnites of the *jaculum*-type. So complete is this change that I was in doubt when previously describing it whether the apparent mingling of the forms at the junction of the zones in the 'Compound-Nodule Band' (D 1) really indicated contemporaneity, or whether through lack of sedimentation the dead remains of the older fauna had lain uncovered on the sea-floor long enough to become embedded in the same layer with the first relics of the new species.[2] I have, however, since found two specimens of the *lateralis*-type of *Belemnites* (*B. subquadratus*, Roem.) distinctly within the zone of *B. jaculum*, the first in the clay immediately overlying D 1, and the second in the clay 18 inches above that band, which proves that the older type was not quite extinct on the appearance of the newer, though very nearly so.

The researches of Prof. Pavlow on the Speeton fossils have thrown new light on the change at this horizon. He has been able to demonstrate that the incoming fauna was one which had been developed and had prevailed in southern seas, while the displaced fauna was markedly northern in its origin and range.[3] The southern fauna remains almost pure throughout the '*noricus*-beds' (C 11 to C 7), but above that zone the *Olcostephani* reappear in a group of species (centring around *Ammonites speetonensis*) which, while distinctly recalling the *Olcostephani* of the upper part of the *lateralis*-zone (D 1 to D 3), are yet so completely modified as to be in every case specifically different. These replace the *Hoplites*-type of ammonites, and though the hastate belemnites (*Belemnites jaculum* and allies) persist much longer, they also eventually disappear, and the field is reoccupied by types (*B. brunsvicensis*) which have probably been derived from ancestors pertaining to the *lateralis*-group.

The line of research thus indicated is still being pursued, and promises to be rich in results bearing on the extent and character

[1] See Mem. Geol. Surv. 'Jurassic Rocks of Great Britain: Pt. I. Yorkshire,' by C. F. Strangways, p. 375.

[2] 'Subdivisions of the Speeton Clay,' Quart. Journ. Geol. Soc. vol. xlv. (1889) p. 589.

[3] 'Argiles de Speeton,' pp. 93, 188 *et seqq.* (sep. cop.) and 'On the Marine Beds closing the Jurassic and opening the Cretaceous, with the History of their Fauna,' by A. Pavlow, in Bull. Geol. Soc. America, vol. iii. (1892) p. 61.

of the life-provinces of the period and the climatic conditions and changes.

The list of the cephalopoda of Speeton as determined by Pavlow has not hitherto been printed in this country, and is therefore given in the Table facing this page. One or two species whose exact position in the series has been ascertained since 1892 are herein for the first time relegated to their proper zones.

Here I beg leave to thank Prof. A. Pavlow and Messrs. E. T. Newton, F.R.S., and G. C. Crick for their invaluable aid and advice in regard to the palæontology, and Mr. J. W. Stather, for his kindly assistance in various ways in the field, and for the loan of his specimens.

III. Inland Extension of the Speeton Series in Yorkshire.

The available evidence respecting the inland prolongation of the Speeton clays is very restricted and unsatisfactory.

Prof. Judd [1] mentions their reappearance about a mile distant from the coast in a stream-course near Reighton; but this exposure seems to have been at all times very obscure, and it is now no longer recognizable.

I am informed that clay like that of Speeton was reached in a well sunk a few years ago near Hunmanby Station, 2 miles from the coast; but I could not learn that any fossils were obtained, and there is consequently no means of determining the horizon.

Farther westward the solid rocks at the foot of the steep escarpment of the Chalk are completely hidden by the drift and alluvium of the Vale of Pickering for about 12 miles; but after this interval the steady rise of the base of the Chalk brings the underlying clays above the valley-flat; and there were at one time some small pits in these clays, near the foot of the slope, in the vicinity of the village of Knapton, from which many fossils were obtained. The excavations, however, have been discontinued for half a century, and the sections are now entirely obliterated. A few fossils obtained many years ago from these old pits have been preserved in our public museums, and these furnish certain valuable though scanty indications with regard to the horizon of the deposits. Prof. Judd has supposed [2] that only the lowest members of the Speeton Series are present in this area, and that the 'Middle' and 'Upper' of his divisions of the coast-section have been cut out by the unconformable overlap of the Chalk. But I have elsewhere shown [3] that while the fossils above mentioned indicate the almost

[1] 'Additional Observations on the Neocomian Strata of Yorkshire and Lincolnshire,' Quart. Journ. Geol. Soc. vol. xxvi. (1870) p. 327. The clay in question is referred in this paper to the 'Zone of *Ammonites speetonensis*'; but as *Belemnites lateralis* is recorded, which species does not occur in the *speetonensis*-beds, while there is no mention of the occurrence of the characteristic *Belemnites jaculum*, I think that the correlation can scarcely be regarded as established.

[2] *Ibid.* p. 329.

[3] 'The Neocomian Clay at Knapton,' The Naturalist (Leeds), Nov. 1890.

TABLE OF THE CEPHALOPODA OF THE SPEETON SERIES.

Zone and Bed.		AMMONITES.	BELEMNITES.
A. Passage-marls *a*.		*a* ***Hoplites interruptus*** ? Brug.	***Belemnites minimus***, List. —— ***attenuatus***, Sow. —— ***ultimus***, d'Orb.
B. Zone of *Bel. brunsvicensis*.		***Hoplites Deshayesii***, Leym. ***Amaltheus bicurvatus***, Mich.	***Bel. brunsvicensis***, Stromb. (pl. vii. (iv.) figs. 9, 10). —— ***speetonensis***, Pavl. (pl. vii. (iv.) figs. 13, 14). —— ***absolutiformis***, Pavl. (pl. vii. (iv.) figs. 11, 12). —— ***Jasikowi***, Lahus. (pl. vii. (iv.) fig. 8). —— ***obtusirostris***, Pavl. (pl. vii. (iv.) fig. 7).
C 1 to upper part of C 6.	Zone of *Belemnites jaculum*.	***Olcostephanus (Simbirskites) Decheni***, Roem. (pl. xviii. (xi.) figs. 4, 5, 6). *b* —— (——) ***umbonatus***, Lahus. (pl. xviii. (xi.) fig. 8). —— (——) ***discofalcatus***, Lahus. (pl. xviii. (xi.) fig. 2). —— (——) ***speetonensis***, Young & Bird (pl. xviii. (xi.) fig. 7). —— (——) ***progrediens***, Lahus. (pl. xviii. (xi.) fig. 15). —— (——) ***concinnus***, Phill. (pl. xviii. (xi.) fig. 16). *b* —— (——) cf. ***Carteroni***, d'Orb. —— (***Holcodiscus***) ***rotula***, Sow. (see below). *b* ***Crioceras*** cf. ***Matheroni***, d'Orb. (pl. xviii. (xi.) fig. 10).	***Belemnites jaculum***, Phill. (pl. vii. (iv.) figs. 2, 3, 4). *c* ? —— ***Jasikowi***, Lahus. (see above). —— ***pistillirostris***, Pavl. —— ***cristatus***, Pavl. (pl. vii. (iv.) fig. 5).
Lower part of C 6 and C 7.		***Olcost. (Simbirskites) subinversus***, M. Pavl. (pl. xviii. (xi.) figs. 12, 13). —— (——) ***inversus***, M. Pavl. (pl. xviii. (xi.) fig. 14). —— (——) ***Payeri***, Toula (pl. xviii. (xi.) fig. 1). —— (——) ***versicolor*** ? Trautsch. —— (***Holcodiscus***) ***rotula***, Sow. (see below). *b* ***Crioceras capricornu***, Roem. (pl. xviii. (xi.) fig. 9).	
C 8 to C 11.		***Hoplites regalis*** (Bean.), Pavl. (pl. xvii. (x.) figs. 1, 2). —— ***amblygonius***, Neum. & Uhl. (pl. xvii. (x.) fig. 6). —— ***oxygonius***, Neum. & Uhl. (pl. xvii. (x.) figs. 4, 5). —— ***Roubaudi*** (***munitus***), d'Orb. (pl. xvii. (x.) fig. 8). —— cf. ***Euthymi***, Pict. (pl. xvii. (x.) fig. 7). *b* ? —— ***heteroptychus***, Pavl. (pl. xviii. (xi.) fig. 22).	***Belemnites subquadratus*** (rare), d'Orb. (pl. vii. (iv.) fig. 1).

certain presence of the upper portion of the Speeton Series in the pits, there is no proof of the existence of the lower zones.

The fossils in question are as follows:—

In the Natural History Museum, South Kensington (in the Bean Collection).

Ammonites (*Hoplites*) *Deshayesii*, Leym. One of the specimens bears a label with the MS. name *A. knaptonensis*, Bean.[1]

Ammonites planus, Phill., probably the young form of *A.* (*Amaltheus*) *bicurvatus*, Mich. I have recently found the same form at Speeton similarly associated with *Hoplites Deshayesii*.

? *Ammonites* (*Hoplites*) *regalis*, Pavl. It is doubtful whether this is really a Knapton species. Two small unlabelled specimens are contained in a tray with other fossils marked 'Knapton,' but in appearance they closely resemble Speeton specimens and differ from the Knapton fossils.

In the Woodwardian Museum at Cambridge.

Terebratulina Martiniana,[2] d'Orb.; labelled *Terebratulina striata*.

In the Museum of the Scarborough Philosophical Society.

Pholadomya (*Martini*, Forbes) ?; in a rather crushed condition.

To these we may also add the following species recorded by Prof. J. Phillips in his 'Geology of the Yorkshire Coast' (3rd ed. p. 242):—

Hamites maximus (mentioned in 1st edition only).
Waldheimia faba, d'Orb.
Rhynchonella lineolata, Phill.

Some further evidence on the subject is afforded by the description of one of the Knapton pits given in 1822 by Young and Bird in their 'Geological Survey of the Yorkshire Coast,' which reads as follows (2nd ed. p. 62):—

'In one of the clay-pits at Knapton we see the junction of the shale with the red and grey chalk. The clay, where it joins the chalk, is soft and plastic; and this, also, is the case with the lower part of the chalk. The two substances are partly blended together; the soft chalk, which occurs here of both colours, approaching to the state of red or grey clay; while the clay that is next the chalk is somewhat impregnated with calcareous matter, and is almost divested of its schistose quality. The same facts are observed in the specimens from the Staxton boring, and at the junction of the chalk and shale in the lower part of the Speeton cliffs.'

This description implies a gradual passage of the Red Chalk into the underlying clay, and is quite opposed to Prof. Judd's view that there is an unconformable overlap of the base of the Chalk at this

[1] From a reference to this species in Young and Bird's 'Geological Survey of the Yorkshire Coast,' I should, however, judge that the name was originally applied by Bean to the ammonite next on the list, namely, *A. planus*, Phill., since the fossil is classed with the *Nautili*, and described as follows:—'A minute flat shell, remarkably smooth, with a small umbilicus and a slight keel, occurs in the upper shale. It resembles some of the ammonite family, and Mr. Bean has named it *A. knaptonensis*' (2nd ed. 1828, p. 272).

[2] I am indebted to Mr. J. F. Walker, M.A., for this determination.

point. The marly passage-beds seem to be exactly similar to those which, as Young and Bird remark, exist at the same horizon at Speeton.[1] The section is now entirely hidden, but near a spring which issues from the base of the Red Chalk at the eastern side of Knapton Plantation, less than 200 yards distant from the largest of the old pits, I have found several fragments of belemnites, trampled out of the clayey subsoil by sheep, and these appear all to belong to the stout variety of *B. minimus* (perhaps = *B. subfusiformis* of some authors), which abounds in the passage-marls at Speeton.

A well-boring at East Heslerton, 2 miles farther east, according to the account given in the Geological Survey Memoir,[2] also passed through 'red clay' immediately below the Chalk, probably denoting the presence of similar passage-marls.

As will presently be shown, the evidence of the western wold-scarp, both in Yorkshire and in Lincolnshire, is likewise in agreement with this interpretation of the Knapton section.[3]

In the more westerly of the Knapton pits, on the slope almost due south of Knapton Hall, the clay seems to have belonged to an horizon altogether lower and not, strictly speaking, referable to any part of the true Speeton Series, a portion of the Kimeridge Clay some little depth below the top being, I think, here represented. I found in one of these old pits a large limestone concretion containing fossils, evidently similar to the septaria referred to by Prof. Judd,[4] which had presumably been rejected when the clay was excavated. This nodule yielded several identifiable fragments of ammonites, which I have every confidence in referring to the well-known Kimeridge species *Ammonites* (*Hoplites*) *eudoxus*, d'Orb., a form known, as mentioned on a previous page, to the old collectors as *A. evalidus*,[5] Bean MS. Phillips also records *Rhynchonella inconstans*, Sow., from the 'Kimeridge Clay, Knapton' ('Geology of Yorkshire,' 3rd ed. 1875, p. 243).

There is, therefore, much probability that we have in this clay the equivalent of 'Bed No. 3' of Leckenby's Speeton section, and that the horizon is well below the summit of the Kimeridgian strata.

Owing to the slipped state of the escarpment on these slopes, it is scarcely possible to make any safe estimate of the thickness of the clay between this pit and the base of the Chalk, but it cannot be great; so that whatever higher beds of the Kimeridge Clay may

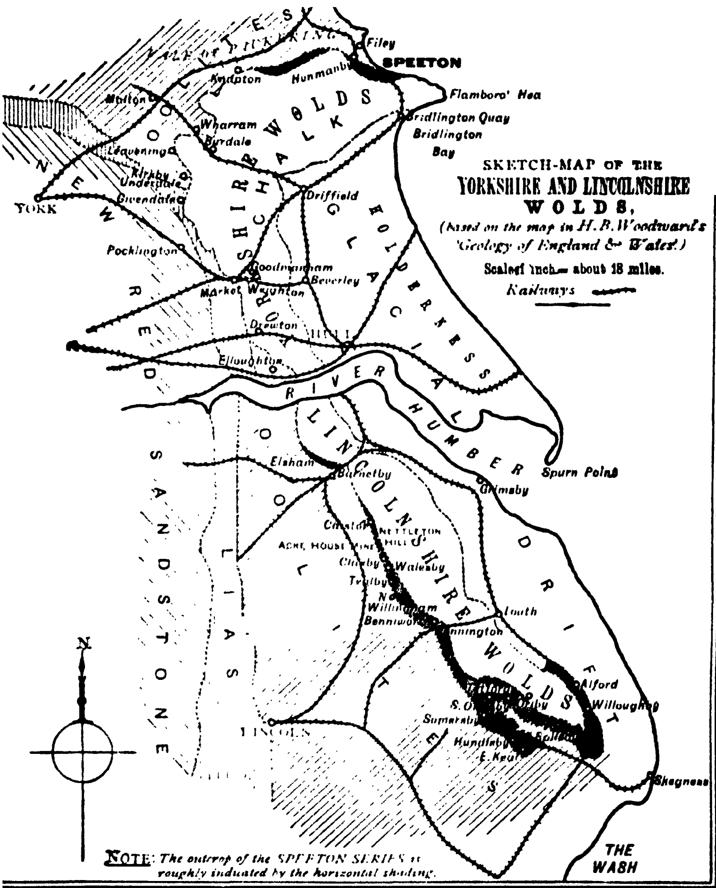
[1] 'On the Subdivisions of the Speeton Clay,' Quart. Journ. Geol. Soc. vol. xlv. (1889) p. 602.

[2] Mem. Geol. Surv. 1880, 'Oolitic and Cretaceous Rocks south of Scarborough,' p. 26.

[3] In Heligoland a similar sequence obtains (see Dames, 'Ueber die Gliederung der Flötzformationen Helgolands,' Sitzungsber. k. preuss. Akad. Wissensch. Berlin, vol. l. 1893, p. 1032), and here also no evidence seems to be forthcoming for the existence of the lowest beds of the Speeton series.

[4] Quart. Journ. Geol. Soc. vol. xxvi. (1870) p. 328.

[5] Prof. Judd mentions the occurrence of this ammonite at Knapton, but considers it (in his later work) as equivalent to *A. fascicularis*, d'Orb., a Lower Cretaceous species, from which, however, it differs in many respects (see a remark as to this in my former paper, Quart. Journ. Geol. Soc. vol. xlv. 1889, p. 613).



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exist, along with all that remains of the Speeton Series, are here contained within a very narrow compass. Somewhere in this vicinity the final thinning-out of the latter must occur, as we find that in going westward from Knapton all trace of the Speeton Series is almost immediately lost, and the Red Chalk, also attenuated, appears to rest directly on the Kimeridge Clay.

From the absence for several miles of any further section revealing the character of the clays immediately beneath the Chalk, it is rather unsafe to assert positively that no clay except the Kimeridge exists in this position, but no proof to the contrary is forthcoming. Four miles west of Knapton the hitherto westerly trend of the Wold escarpment is rather suddenly changed for a southerly or south-south-easterly direction, which persists up to, and beyond, the Humber, to the end of the Wolds in Lincolnshire. In the neighbourhood of the bend the character of the base of the Red Chalk undergoes an important alteration, by which, instead of presenting a gradual passage into the clays, it assumes a pebbly or conglomeratic aspect,[1] and preserves this character in a greater or less degree throughout the whole extent of its course along the western margin of the Yorkshire and Lincolnshire Wolds. Some information regarding the underlying clays may be gleaned from the old spoil-heaps of the Burdale tunnel on the Malton and Driffield railway. The northern end of this tunnel has been excavated for some distance in the clays, and has cut their junction with the Chalk. Such fossils as I have been able to recognize among the débris are all Kimeridgian forms, and none proper to the Speeton Series have been found. Fragments of belemnites are rather abundant, apparently referable mostly to the Kimeridgian species *B. explanatus*, Phill., with perhaps also *B. Troslayanus*; and an imperfect specimen of the former species was obtained from the clay in the banks of the little stream at Wharram Percy. It seems clear that in this region elevation and erosion were going on contemporaneously with the steady deposition of muddy sediment in the submerged area to the eastward, and that these conditions continued to prevail until the setting-in of that slow and persistent depression which brought about the accumulation of the great Chalk-formation.

Along the western margin of the Yorkshire Wolds the pebbly base of the Red Chalk is generally the only relic of this period, but in a few places the conglomeratic band thickens locally into a sandy deposit resembling the Carstone of Lincolnshire, and like it separable from the overlying Red Chalk.[2] Of this the best example known to me occurs at the head of Scotten Dale, the deep valley east of Kirby Underdale, 13 miles E.N.E. of York.[3] In this locality

[1] See W. Hill, 'On the Lower Beds of the Upper Cretaceous Series in Lincolnshire and Yorkshire,' Quart. Journ. Geol. Soc. vol. xliv. (1888) pp. 334–35.

[2] J. F. Blake, Proc. Geol. Assoc. vol. v. (1877) p. 245.

[3] The Rev. J. F. Blake seems to have been the first to call attention to this interesting section, see Geol. Mag. 1874. p. 363, and *op. jam cit.* p. 246. See also C. F. Strangways, Geol. Surv. Mem. 'The Geology of the Country N.E. of York and S. of Malton,' p. 25.

at the time of my last visit the following section could with some difficulty be made out on the steep southern side of the vale:—

	Ft.	In.
White chalk not well exposed.		
6. Hard, pinkish and yellowish, nodular chalk .... seen for about	2	0
5. Deep-red and yellowish nodular chalk. *Belemnites minimus* and fragments of *Inoceramus* abundant .... seen for about	2	0
4. Soft, shaly, red chalk	0	3
3. Hard, gritty, nodular red chalk. *B. minimus* abundant...........	1	0
2. Yellow clayey marl with ferruginous grains. *B. minimus* and *Terebratula*, sp. were found at this horizon apparently in place; but the conditions suggested a slight possibility of their having been washed down from the overlying red chalk...........about	1	0
1. Coarse, pebbly, ferruginous sand of deep-brown colour well seen for	3-6	
Total thickness probably about 12 feet. Pebbles range up to 2 inches in diameter, composed of oolitic ironstone and phosphatized nodules, with small black shining 'lydites,' quartz-grains, etc.		
Dark blue clay, referred to the Upper Lias.[1]		

In this section the marly layer, No. 2, which appears to contain sparingly certain characteristic Red Chalk fossils, distinctly suggests a passage downward from the Red Chalk into the underlying unfossiliferous ferruginous sands; and the latter deposit so closely resembles the Lincolnshire Carstone in its general appearance and in its relationship to the Red Chalk that I think we may unhesitatingly accept the Rev. J. F. Blake's proposal that it should be correlated with the Carstone.

Mr. W. Hill has suggested[2] that the character of the base of the Red Chalk in general may be explained as resulting from the 'working up' of the underlying material during its deposition. But I think that in the above section, as at Knapton and at Specton, there is good evidence for an actual downward passage at this horizon. The Yorkshire sections are thus in agreement with those of Lincolnshire, in which county, as Mr. A. Strahan has shown,[3] there is everywhere the closest stratigraphical relationship between the Red Chalk and the underlying Carstone, often with clear proof of a gradual passage from one to the other.

Traces of deposits similar to that of Scotten Dale occur in various places both north and south of this locality, as at Wharram,[4] Leavening,[5] Givendale[6], etc., but always of greatly reduced thick-

[1] Mem. Geol. Surv. 'Country N.E. of York and S. of Malton,' p. 10.

[2] W. Hill, Quart. Journ. Geol. Soc. vol. xliv. (1888) pp. 338, 355.

[3] A. Strahan, 'On the Relations of the Lincolnshire Carstone,' Quart. Journ. Geol. Soc. vol. xlii. (1886) p. 486, also Mem. Geol. Surv. 1888, 'Country around Lincoln,' p. 105. In these opinions Mr. A. J. Jukes-Browne does not concur (Mem. Geol. Surv. 1887, 'East Lincolnshire,' p. 15, footnote). After examining most of the Lincolnshire sections, however, I am convinced that Mr. Strahan's s on this matter are correct.

[4] J. F. Blake, Proc. Geol. Assoc. vol. v. (1877) p. 245.

[5] W. Hill, Quart. Journ. Geol. Soc. vol. xliv. (1888) p. 341.

[6] J. F. Blake, Geol. Mag. 1874, p. 362.

ness and insufficiently exposed for study. In its still more attenuated form, as the pebbly basement-layer of the Red Chalk, it was revealed a few years ago in the railway-cutting of the Market Weighton and Driffield branch east of Goodmanham, being here of very coarse texture, with fragments of phosphatic stone and coarsely-gritty oolitic iron-ore, up to 3 or 4 inches in diameter. In this vicinity the unconformability at the base of the Upper Cretaceous rocks reaches its extreme stage, the underlying strata being shaly limestone of Lower Lias age; and in going farther south we find that the higher members of the Jurassic series emerge again in succession.

In the extensive cuttings near Drewton, 4 miles north of the Humber, on the Hull and Barnsley railway, the base of the Red Chalk was at one time excellently exposed, and is still partially visible. These sections while still fresh were examined by Messrs. W. Keeping and C. S. Middlemiss, who record the following details[1] :—

	Feet.	Inches.
Nodular red chalk	1	6
Pale nodular chalk	1	3
Clayey red chalk	0	6
Grey nodular chalk	1	0
Red chalk	0	3
Yellow-green clay	0	9
Unctuous red clay	1	6

resting on a 'dark, almost black clay, slightly shaly .... probably the Kimeridge Clay, but characteristic fossils were not obtained.'

It has been suspected that the uppermost portion of the dark clays beneath the above may represent some portion of the Speeton Series,[2] and the clayey character of the base of the Red Chalk seems to favour the supposition. But a careful search has failed to reveal any evidence of the presence of the Speeton fauna, the first fossils met with below the Red Chalk being, as Messrs. Keeping and Middlemiss pointed out, undoubtedly Jurassic forms, including *Belemnites abbreviatus* and *B. Owenii*. On general considerations, however, it seems just possible that some of the unfossiliferous clay immediately below the Red Chalk may represent the sparingly fossiliferous marls with *Belemnites minimus* (A) which have been shown to occupy this horizon at Speeton and Knapton, though, as one of the cuttings still exhibits traces of a pebbly band at the base of the Red Chalk, it is more likely that the Speeton Series is entirely absent at this point.

Nearer the Humber, in a small pit in the dale north of Elloughton, the Red Chalk is seen to contain numerous small pebbles, and probably has a similar pebbly base, the underlying deposit again being dark clay, supposed to be Kimeridge Clay.

[1] 'On some New Railway Sections and other Rock-Exposures in the District of Cave, Yorkshire,' Geol. Mag. 1883, p. 218.

[2] A. Harker, 'The Oolites of the Cave District,' The Naturalist (Leeds), 1885, p. 231.

The sum of the available evidence regarding the inland extension of the Speeton Series in Yorkshire indicates, therefore, that these rocks undergo a rapid attenuation as a whole in a westerly direction, and that all disappear within 14 miles of the coast except the uppermost division (*Belemnites minimus*-marls: Zone A), which persists as the pebbly or clayey basement-layer of the Red Chalk, swelling locally into a thicker deposit of ferruginous sand akin to the Lincolnshire Carstone.

The data are insufficient to prove whether the Lower Cretaceous Clays end off against the edge of their basin of deposition, and are simply overstepped by the Upper Cretaceous strata; or whether a true unconformability, as in so many other parts of the country, is developed in them at this horizon. That erosion took place in the western part of the district before the deposition of the Red Chalk is indeed certain; but it is not certain that the clays of the coast-section ever extended so far westward.

IV. The Speeton Series in Lincolnshire.

a. General Observations and Bibliography.

With respect to the Lincolnshire sections my present purpose has regard for the sequence of the rocks rather than for their local stratigraphy; and as the whole area has been recently examined and reported upon by the officers of the Geological Survey, whose maps and memoirs[1] afford all the necessary information bearing on the mode of occurrence and extent of the various strata to be considered, it will be neither requisite nor desirable that I should reiterate such details. My aim therefore will be to give the broader outlines only of the general stratigraphy, but to enter more fully into the palæontological and other evidence which may afford the means for the correlation of the rocks in question with the more easily classified clays of the Speeton section. And indeed, though during the course of my field-work in this area I have gone repeatedly over the whole extent of the Lower Cretaceous outcrop, I have concentrated my attention chiefly on such places as promised the best palæontological results. The most suitable localities for this purpose have proved to be the broken escarpment near Acre House, with its abandoned iron-ore workings; the limestone-pits of Normanby, Walesby, Tealby, and Willingham; the fine railway-cutting sections on either side of Donnington-upon-Bain; and the brickyards and sand- and sandstone-pits of the Spilsby district.

Of the palæontological material collected only a small portion can be adequately dealt with at present, but fortunately the cephalopoda are sufficiently abundant and characteristic to allow of definite

[1] Sheets (one inch) Nos. 86, 84, and 83. Memoirs, 'North Lincolnshire and South Yorkshire' (Sheet 86); 'Country around Lincoln' (Sheet 83); and 'East Lincolnshire' (Sheet 84).

conclusions being drawn respecting the correlation of these Lincolnshire deposits with the Speeton Series of the Yorkshire coast, thereby clearing away certain prevalent misconceptions and providing a safer basis for future discussion of their age and origin.

These beds seem to be unrepresented at the northern extremity of the Lincolnshire Cretaceous escarpment, the pebbly base of the Red Chalk in the vicinity of the Humber resting, so far as is known, directly on the Kimeridge Clay.[1] About 6 miles south of that estuary, however, thin sands and clays intervene for a short space between the Kimeridge Clay and the Chalk, but are not well exposed, and are soon again altogether lost beneath the overlapping Chalk. They reappear in stronger force after a further interval of about 5 miles; and thenceforward, from the neighbourhood of Caistor, are continued southward, gaining steadily in importance, up to the southern termination of the Chalk escarpment, 8 miles north of the Wash, where the drift and alluvium of the low ground enshroud them.

Where best developed the diverse lithological characters of this series have afforded a ready and simple method of subdivision which has been adopted by all its investigators. These divisions are shown in the Table printed on p. 194, in which the results of previous workers are stated and compared.

In addition to the papers mentioned in the Table, Mr. H. Keeping gave in 1882 a short but valuable account of the series,[2] and especially of the sections on the Louth and Lincoln railway, now in great part obscured, from which he had in 1872 secured a large collection of fossils. His classification is essentially that of Prof. Judd and the earlier observers; but he seems to have been the first to call attention to the band of phosphatic nodules at the base of the Spilsby Sandstone, and his fossil lists are in many respects in advance of those of his predecessors, though herein, as in all the other palæontological lists of the area yet published, the confusion of *Belemnites brunsvicensis* with *B. lateralis*,[3] and the vagueness of the specific names employed for the ammonites, seriously impair their value as aids to the correlation of the deposits.

The detailed comparisons of the Speeton section with the Lincolnshire deposits previously put forward are shown in the Table facing this page.[4]

[1] A. Strahan, 'On the Lincolnshire Carstone,' Quart. Journ. Geol. Soc. vol. xlii. (1886) p. 489.

[2] H. Keeping, 'On some Sections of Lincolnshire Neocomian,' Quart. Journ. Geol. Soc. vol. xxxviii. (1882) p. 239.

[3] The same error pervades nearly all the fossil-lists given by Prof. Judd and the Survey, and also affects the Continental lists in Judd's paper in Quart. Journ. Geol. Soc. vol. xxvi. (1870) p. 326.

[4] The correlation given in the late Mr. W. Keeping's 'Fossils, etc., of Upware and Brickhill' (Cambridge, 1883), p. xi. is omitted, being practically a reproduction of that of Prof. Judd. There is also a brief correlation by Mr. A. J. Jukes-Browne in his paper 'On the Application of the term Neocomian' (Geol. Mag. 1886, p. 311), based upon Prof. Judd's account of the Speeton sections.

The scheme first proposed by Pavlow in 1889, after his preliminary study of the fossils of the deposits, and afterwards more fully stated and slightly amended in 1891–92, is substantially that which I brought before the British Association in 1890, and reproduced in 'Argiles de Speeton et leurs Équivalents' in 1891; and between this and the propositions of the previous workers there are radical differences.[1] Further investigation has fully confirmed the correlation suggested by Pavlow and myself, and it is now sought to place on record the field-evidence, not heretofore published, by which the comparison is sustained. Amid the general discussion of this evidence some side-issues will be debated which are of much consequence to the right understanding of the relations of the series as a whole. The deposits will be considered in their upward stratigraphical sequence.

b. The Kimeridge Clay.

In comparing the Yorkshire and Lincolnshire areas we possess in the Kimeridge Clay an admirable base-line.

Though, owing to the crushed condition of the fossils in both districts, the list of recognizable species in common is short, the general similarity in position and composition is so close that no reasonable doubt can exist that the bituminous shales[2] which underlie the Spilsby Sandstone everywhere to the southward of Caistor in Lincolnshire are the equivalents of the similar shales (Zone F) underlying the 'Coprolite bed' (Zone E) of the Speeton section, and were laid down in the same basin of deposition.

It is indeed possible that the uppermost portion of this deposit may have been locally removed by erosion in certain areas in Lincolnshire previous to the deposition of the Spilsby Sandstone, since the researches of the Geological Survey have gone to show that there is a definite unconformable overlap of that rock in the northern part of the county;[3] and the absence, so far as is yet known, of the large belemnites of the *Owenii*-group (*Belemnites magnificus*, *Puzosi*, etc.), which occur at Speeton at the top of the bituminous shales, may perhaps be thus accounted for. These fossils are, however, by no means common even in the shore-exposures at Speeton, and it may well be that their apparent absence in Lincolnshire arises only from the lack of good collecting-ground at this horizon.

[1] With respect to the Geological Survey publications, it is to be noted that the Lincolnshire deposits containing *Belemnites lateralis* are fully described in the recently-published Mem. Geol. Surv., 'The Jurassic Rocks of Great Britain,' vol. v. (pp. 286 *et seqq.*), and the corresponding portion of t[...] Clay in vol. i. (Yorkshire) of the same series, and this seems to imply an acceptance of the views of Prof. Pavlow respecting their age, though no very definite opinion is in either case expressed. See second division of Table of comparisons.

[2] For further information regarding the Kimeridge Clay, see J. F. Blake, Quart. Journ Geol. Soc. vol. xxxi. (1875) pp. 196–233; T. Roberts, *ibid.* vol. xlv. (1889) pp. 545–560, and Geol. Surv. Mems., *jam cit.*

[3] Mem. Geol. Surv. 1888, 'The Country around Lincoln' (Sheet 83), p. 82.

Subdivisions of the Infra-Cretaceous Strata in Lincolnshire according to the several Observers undermentioned.

Geological Survey. 'East Lincolnshire,' Mem. Sheet 84. 1887; 'Country around Lincoln,' Sheet 85. 1888; and 'North Lincolnshire, etc.,' Sheet 86. 1890.	J. W. Judd. 'On the Strata which form the base of the Lincolnshire Wolds,' Quart. Journ. Geol. Soc. vol. xxiii. (1867) p. 227, and 'Additional Observations,' etc., Quart. Journ. Geol. Soc. vol. xxvi. (1870) p. 326.	W. H. Dikes and J. E Lee. 'Outlines of the Geology of Nettleton Hill, Lincolnshire,' Mag. Nat. Hist. 2nd ser. vol. i. (1837) p. 561.	Ed. Bogg. 'Outlines of the Geology of the Lincolnshire Wolds,' Trans. Geol. Soc. ser. 1. vol. iii. (1816) p. 392.
Red Chalk.	Hunstanton Red Rock.	Red Chalk.	'Stratum No. 2' (lower part of).
	(unconformity)		
Carstone.	Upper Ferruginous Sands.	The Thoresway Sand.	'No. 3.'—A coarse, brown, pebbly sand without organic remains.
Tealby Beds { Upper Ironstone and Clay, Tealby Limestone = 'Roach' Ironstone in Sh. 84. Tealby Clay. Claxby Ironstone.	Tealby Series { Tealby Limestone and Clay. Oolitic Ironstone.	The Grey-stone. { 'A mass of small, globular, shining grains of a dark brown colour, cemented together by ferruginous matter.'	'No. 4.'—Nearly equal proportions of oolite limestone and calcareous clay of a lightish grey colour, etc.
Spilsby Sandstone (with pebble-bed of derived phosphatic nodules at the base).	Lower Sands and Sandstone.	The Greensand and Sandstone.	'No. 5.'—Stratum of quartz-grains, sometimes conglomerated into sandstone, and then containing fossils.
(unconformity)	(unconformity)		
Kimeridge Clay.	Kimeridge Clay.	Kimeridge Clay.	'No. 6.'—A shale stratum, bituminous, pyritous, and calcareous.

But, with this reservation respecting the uppermost part, we may safely state the general equivalency of the Upper Kimeridge deposits of Yorkshire and Lincolnshire.

c. The Basement-bed of the Spilsby Sandstone.

The base of the pale greenish or reddish quartzose sand or sandstone which overlies the Kimeridge Clay everywhere in Lincolnshire southward of Caistor is marked by the presence of numerous dark phosphatic nodules, usually from 1 to 3 inches in diameter.

At Speeton there is at the same horizon a similar though more compact band of 'coprolites' (Zone E), and in this respect the two areas are distinctly comparable. These nodules, first noticed as above mentioned, by Mr. H. Keeping in a railway-cutting near South Willingham, were afterwards traced by the officers of the Geological Survey over an extended area,[1] and by them were considered to be derivative pebbles marking the destruction of pre-existing deposits. It appears to me, however, that the derivative character of these nodules is exceedingly doubtful, this view being liable to the same objections as apply under similar circumstances at Speeton.[2]

The composition of the so-called pebbles tells strongly against their derivative origin. Wherever I have been able to examine them they have been of uniform character, without admixture, and have all presented the same dark phosphatic exterior and eroded aspect. But in many instances when broken open they reveal a gritty interior not unlike that of the overlying sandstone, and when dissolved in acid they leave an abundant residue of somewhat coarse quartzose sand, which distinctly suggests their original accretion in a sandy matrix like that now enclosing them, and is not to be reconciled with the idea that they were once concretions in the Kimeridge Clay. Moreover at Speeton, where the nodules are enclosed in pyritous clay, the only residue obtained on dissolving them is a little dark fetid mud with groups of angular pyrites-crystals and a very little fine sandy silt. They occur in both localities mostly in the form of more or less obscure casts of shells and portions of the whorls of ammonites, sometimes riddled with the tube-like cavities of boring molluscs; and these fossils, when recognizable, are distinctly not such as characterize the subjacent strata or any other deposit of a lower horizon now existing in the areas. The specific determination of these casts is of course full of difficulty and uncertainty, as is shown by the state of the lists published in the Geol. Surv. Mems.[3] from the collection made in Lincolnshire by Messrs. A. J. Jukes-Browne and M. Staniland. The lists contain a total of nineteen determinations; but in only eight

[1] Mem. Geol. Surv. 1888, 'The Country around Lincoln,' pp. 89 *et seqq.*, and *ibid.* 1887, 'East Lincolnshire,' pp. 15 *et seqq.*

[2] 'Subdivisions of the Speeton Clay,' Quart. Journ. Geol. Soc. vol. xlv. (1889) p. 586.

[3] 'East Lincolnshire,' p. 139; 'Country around Lincoln,' p. 93.

instances is the species stated, the remainder giving the genus alone. Moreover a footnote is added to the lists expressing great hesitancy in the identifications. The following are the fossils mentioned:—

SPECIES: *Terebratula ovoides*, Sby., *Waldheimia Woodwardii*, *Myacites recurva*, *Lucina portlandica*, Sby., *Thracia Phillipsii*, Roem. (or *depressa*, Sby.), *Ammonites biplex*, Sby., *A. plicatilis*, and *A. speetonensis*, Y. & B.

GENERA: *Arca*, sp., *Astarte*, *Cyprina*, *Cucullæa*, sp., *Isocardia*?, *Lima*, sp., *Pectunculus*, sp., *Trigonia*, sp., *Natica*, sp., *Pleurotomaria*, sp., *Belemnites*, sp.

In discussing this list we may at once dismiss the genera, remarking only that the rotund form of the casts, the presence of the impression of both valves in the case of bivalves, the absence of fragments of oysters and other characteristic hard fossils occurring abundantly in the underlying strata, and the general facies of the assemblage, are all points which tell against the derivative origin of the nodules. But when we turn to the consideration of the species above-mentioned, we do not find any better evidence in support of the statement that 'there can be no doubt that most of the phosphates have been derived from the Kimeridge Clay' ('East Lincolnshire,' p. 139). *Terebratula ovoides*, Sby., if it be the species mentioned by Mr. W. Keeping,[1] has been found in blocks supposed to have been derived from the Spilsby Sandstone, and also in a phosphatized condition at Upware, Brickhill, and Potton, and therefore if the species be rightly determined the evidence is entirely against its derivative character. *Waldheimia Woodwardii*, Walker, is not known to exist in rocks of a lower horizon. *Myacites recurva* is referred to at the foot of the list as being a form which 'might equally well be *Panopæa neocomiensis*; and on the other hand *Thracia Phillipsii* may well be *Th. depressa* of the Kimeridge Clay.' *Lucina portlandica* occurs commonly at Speeton as a cast in the 'Coprolite-bed' (Zone E), and appears to be confined to this horizon both in Yorkshire and Lincolnshire. *Ammonites biplex*, as the name is usually applied in England, is almost without determinative value even when the specimens are well preserved, since almost every round-whorled ammonite with bifurcating ribs, from whatever horizon, has in turn received the title, whether it be of the genus *Perisphinctes* or *Olcostephanus* or what not. In some of our public collections, for example, specimens from the Upper Kimeridge have been mixed with others undoubtedly from the 'Zone of *Ammonites speetonensis*' of the Speeton Clay under the common name of *A. biplex*.[2] *A. speetonensis* stands in exactly similar case, being a much-abused species into which it has been the fashion of English palæontologists to thrust almost any form of the genus *Olcostephanus* that had the misfortune to be found anywhere between the base of the Red Chalk and the top of

[1] W. Keeping, 'Fossils of Upware, etc.,' Cambridge, 1883, pp. 34–37.

[2] See Quart. Journ. Geol. Soc. vol. xlv. (1889) p. 613. The last-mentioned form, *Ammonites concinnus* of Phillips, is recognized by Pavlow as including *Olcostephanus* (*Simbirskites*) *subinversus*, M. Pavl., and other allied species.

the Kimeridge Clay. *A. plicatilis*, another 'difficult species,' is usually considered an Oxfordian and Corallian form, and under the circumstances the value of the determination is altogether doubtful. These fragments of ammonites are in fact similar to those occurring abundantly in the 'Coprolite-bed' (E) of Speeton in like preservation, which Prof. Pavlow has studied and illustrated in 'Argiles de Speeton' (pl. ii. & pp. 114 and 115), and considers to be the relics of a fauna not otherwise represented in the section. The species he has identified from Speeton are given in the Table of Cephalopoda facing p. 184. Thus we see that both the composition of the nodules and their fossils tell strongly in favour of their original accretion at their present horizon.

The weakness of the fossil evidence for their derivative character was evidently felt by the writer of the 'East Lincolnshire' memoir, who therefore puts forward the further suggestion that 'it is just possible that there were certain older Neocomian beds (destroyed before the deposition of the Spilsby Sandstone), and that some of the casts were derived from them.' But as it will presently be demonstrated that the Spilsby Sandstone represents the lowest horizon of the Speeton Clay (which has been shown by recent researches to be older than any known Neocomian rocks and more closely allied to the Jurassic than to the Lower Cretaceous), and as the palæontological evidence demonstrates that there are no beds missing at this horizon in Lincolnshire which occur in Yorkshire, where, if my reading of the section be correct, there is practically an unbroken record from Jurassic to Upper Cretaceous times, it is difficult to believe that the supposed beds can ever have existed in the area.

Except in one particular, the nodule-bed of Lincolnshire is indeed in all respects analogous to the 'Coprolite-bed' of Speeton, the difference being that while the latter occurs as a band in the midst of a conformable clayey or shaly series, and does not mark any striking lithological change, the former is developed along a very important stratigraphical horizon at which the great clayey series of the Middle and Upper Jurassics gives place to the coarse sandy deposit forming the Spilsby Sandstone, a change evidently betokening a wide-reaching revolution in the physical conditions of the region. There seems moreover, as already stated, to be evidence of actual erosion and unconformability at this horizon as we approach the Humber,[1] and it is therefore the more remarkable that the nodule-bed should not contain better indications of the destruction of the older strata if any 'pebbles' were really derived therefrom. But all the arguments which at Speeton[2] tell in favour of the formation of these phosphatic stones as nodules contemporaneous with the deposit have equal strength in Lincolnshire. In both districts the stones, though most abundant at a definite horizon, are by no means confined to it, but occur at other levels,

[1] See Geol. Surv. Mem. 1888, 'Country around Lincoln,' p. 82.
[2] Quart. Journ. Geol. Soc. vol. xlv. (1889) p. 584.

or sparsely scattered throughout the series; they contain certain fossils proper to the bed in which they occur; and their eroded surfaces show less appearance of rolling than of corrosion from the attack of various destructive organisms inhabiting the sea-floor, whose activity is similarly manifest on the undoubtedly indigenous fossils of the deposits.

The subject thus raised has broad bearings, and if my view be correct there are many localities other than those now in question where a revision of the evidence for the derivative character of the 'phosphate-stones' is desirable. I am satisfied, for instance, from a recent examination at Hunstanton of the mode of occurrence of *Hoplites Deshayesii* and other fossils thus preserved towards the base of the Carstone, that these are proper to the deposit and not derivative;[1] and a study of the literature relating to the 'phosphate-beds' at Potton, Wicken, Upware, etc.,[2] shows that most of the investigators of these localities have found it necessary to allow that some at any rate of the nodular material is not older than the bed in which it occurs.

It is not my purpose, however, to pursue the wider question on this occasion,[3] and I shall content myself for the present by restating my conviction, based on a careful study of the various types of nodules and concretions marking the different horizons of the Speeton Clay, that some of these, including the dark phosphatic stones, have gathered in the mud of the sea-bottom, and have formed hard masses before the accumulation of the overlying strata,[4] and that the comparative rarity or abundance of concretions of this type affords a rough measure of the rate of deposition of the enclosing material.

The investigations of the *Challenger* expedition[5] have taught us that the formation of nodules both of phosphate and manganese is still taking place in areas of slow deposition beneath our existing oceans, and from the description given of the former they appear to agree remarkably in shape, size, and general characters with those under consideration. It is true that the conditions are in many respects not analogous, but the phenomena are probably, none the less, closely illustrative of those of our Jurassic and Cretaceous seas, wherein the marine sediments seem to have been characterized by

[1] See reference to these in W. Keeping's 'The Fossils of Upware and Brickhill,' Cambridge, 1883, p. 57.

[2] Among other works see J. J. H. Teall, 'The Potton and Wicken Phosphatic Deposits' (Cambridge, 1875); W. J. Sollas, Quart. Journ. Geol. Soc. vol. xxix. 1873, p. 76; W. Keeping, *op. jam cit.* p. 17. See also the discussion between Walker, J. F. (Ann. & Mag. Nat. Hist. ser. 3, vol. xviii. 1866, pp. 31 & 381, and xx. p. 118), and H. G. Seeley (Ann. & Mag. Nat. Hist. ser. 3, vol. xviii. p. 111, and xx. p. 23); and O. Fisher, Quart. Journ. Geol. Soc. vol. xxix. (1873) p. 52.

[3] For an excellent summary of our knowledge on this subject, with extensive bibliography, see R. A. F. Penrose, Jun., 'Nature and Origin of Deposits of Phosphate of Lime,' Bull. U.S. Geol. Surv. vol. vii. no. 46 (1888), p. 475.

[4] At the meeting of the Geol. Soc. previous to that at which this paper was read, Messrs. A. J. Jukes-Browne and Hill put forward a very similar explanation for the phosphatized fossils and nodules of the 'Cénomanien.'

[5] *Challenger* Reports, 'Deep-Sea Deposits' (London, 1891), p. 391.

an exceptionally high percentage of phosphoric acid.[1] After such nodules were formed a local increase in the strength of the current appears often to have wafted away the matrix, and the harder matter was thus exposed to the corrosive action of the sea-water and its denizens, producing on the nodules a misleading appearance of wave-erosion.

As to the length of the pause in the sedimentation denoted by these bands of nodules, we can judge only from the evidence of other regions where the interval is more fully represented, or from the change to be noted in the fauna of the strata above and below such bands. In this particular instance Prof. Pavlow, as already mentioned, believes that an ammonite-zone well developed in Russia is at Speeton condensed into these 4 inches of nodular matter.

d. The Spilsby Sandstone.

The lithological and stratigraphical characters of this deposit have already been sufficiently indicated. Where it occurs in the condition of a loose sand the fossils exist only in the form of obscure hollow casts; but it usually consists in part of irregular concretionary masses, often extremely hard, in which fossils are frequently abundant, though difficult to extract and sometimes injured by crushing. The most prominent feature of the fauna is the abundance of the bivalve mollusca, mainly referable to the genera *Pecten*, *Pinna*, *Lima*, *Trigonia*, *Panopæa*, etc., many of which are well preserved. But a glance at the published lists[2] will suffice to show the uncertain state of the nomenclature, and as it is not in my power at present to give more precise information regarding these fossils, I do not propose herein to discuss them further than to state that I can recognize among them some forms which occur at Speeton in the 'Pale Beds' (D 6 and 7) of the zone of *Belemnites lateralis*, and that several species could be matched, I think, in the Hartwell Clay and equivalent Jurassic strata further south.[3]

[1] Considering the clear evidence which we now possess of the alternating encroachments of a northern and a southern fauna into certain parts of the North European basin during the epoch of the formation of the rocks between the Kimeridge Clay and the Chalk, and the plentiful occurrence of phosphatic nodules where the northern and southern faunas meet, in the compound-nodule band, D 1, at Speeton, the following passage in the *Challenger* Report relative to the mode of occurrence of the recent nodules is at least worth noticing (p. 396):— 'It may be pointed out that phosphatic nodules are apparently more abundant in the deposits along coasts where there are great and rapid changes of temperature, arising from the meeting of cold and warm currents, as, for instance, off the Cape of Good Hope and off the eastern coast of North America. It seems highly probable that in these places large numbers of pelagic organisms are frequently killed by these changes of temperature, and may in some instances form a considerable layer of decomposing matter on the bottom of the ocean.'

[2] Geol. Surv. Mem. 1887, 'East Lincolnshire,' p. 140; H. Keeping, Quart. Journ. Geol. Soc. vol. xxxviii. (1882) p. 241; Geol. Surv. Mem., 'Jurassic Rocks of Great Britain,' vol. v.

[3] [Since this paper was read, Prof. Pavlow has described and figured *Aucella volgensis*, Lahus., and *Aucella volgensis*, var. *radiolata*, Pavl., both found in the 'zone of *Ammonites stenomphalus*' in Russia, from the Spilsby Sandstone of Donnington (see p. 213).—April 22nd, 1896.]

The cephalopoda are decidedly less abundant than the lamellibranchiata, but fortunately are still sufficiently numerous and characteristic to provide safe grounds for the correlation. The belemnites are widely, though scantily, distributed, and all the specimens yet discovered are of the *lateralis*-type (*Belemnites explanatoides*, Pavl.; *B. lateralis*, Phill.; *B. russiensis*, d'Orb.), forms occurring in the lower part of Zone D at Speeton.

The ammonites, though less rare, are not, as a rule, well preserved. They have been referred by English palæontologists to various species of obscure antecedents, such as *Ammonites plicomphalus*,[1] Sby.; *A. mutabilis*, Sby.; *A. Kœnigi*, Sby.; *A. rotundus*, Sby.; all names more or less vaguely applied in England, but usually to Jurassic forms. More recently Pavlow[2] has identified, among other species, *Olcostephanus* (*Craspedites*) *subditus*, Trautsch., a well-known Continental form of great value in the correlation. At Speeton the corresponding horizon appears to be found in beds 5, 6, and 7 of Zone D. These are almost devoid of identifiable ammonites,[3] but the correlation is, I think, well established by the belemnites, combined with the evidence of the overlying and underlying strata. I have no doubt that, when the remaining branches of the fauna have been more thoroughly studied, a relatively large number of the species will be found to be common to the two areas.

It is very probable, however, as will presently appear, that the upper boundary of the Spilsby Sandstone is not everywhere of exactly the same age, the accumulation of sandy material having persisted longer in some localities than in others.

e. The Claxby Ironstone.

The paucity of sections in the Lincolnshire area is especially detrimental when we attempt to deal with this deposit and the overlying Tealby Clay. In the neighbourhood of Caistor, and for

[1] As illustrating some of the difficulties of the palæontology it may be noted that, of Sowerby's two types of *Ammonites plicomphalus* now preserved in the Natural History Museum, one is labelled as from 'Kelloway Rock, Bolingbroke,' and the other 'Kimeridge Clay.' Both are in a matrix of Spilsby Sandstone. In all the collections, fossils from the different horizons in Lincolnshire are much mixed.

[2] 'Argiles de Speeton,' p. 116 (sep. copy).

[3] In collecting from the 'Pale Beds' (D 6) at Speeton I have obtained curious evidence of the former existence of large ammonites at this horizon. Full-grown *Exogyræ* (*sinuata*, var. cf. *Couloni*) are of common occurrence, and one of these presented on one surface an excellent cast of a segment of the interior whorls and ribs of a large ammonite, to which the oyster had evidently been affixed. The cast is insufficient for specific determination, but shows clearly that the ammonite has not been of the deep-whorled *Polyptychites*-type such as tenant the overlying beds, but may have been akin to the *Craspedites*-group of C

few miles farther south, the Spilsby Sandstone is capped by this band of oolitic, clayey, and sometimes slightly gritty ironstone crowded with fossils, which is about 15 feet thick in the brow of the hill south of Nettleton, where it has been mined, but probably not elsewhere so thick. In this locality both the upward and the downward limits of the ironstone-rock are fairly definite, but it is usually overlain by a clayey band crowded with oolitic ferruginous grains which appears to contain the fauna of the ironstone along with a few newer forms. Northward it seems to thin out and disappear shortly before the accompanying strata are overlapped by the Upper Cretaceous rocks near Clixby. In the opposite direction it is still a well-marked feature in the series 12 miles south of Nettleton, the railway-cutting at Benniworth Haven, near Donnington, described by Mr. H. Keeping,[1] revealing 9 feet of this rock, while its original thickness may have been more than this; but farther south it appears to merge more or less into a clayey deposit. At the southern termination of the Wolds it is represented by irregular gritty ferruginous bands with deep partings of sandy clay. East of the Wolds it was recognized in the borings at Willoughby and Skegness, and in both localities was interstratified and mixed with clay.[2]

By Prof. Judd and the officers of the Geological Survey the Claxby Ironstone is classed with the Tealby Clay; but the earlier observers, Messrs. Dikes and Lee, were inclined to connect it with the underlying sandstone,[3] and Mr. H. Keeping observes that its fossils 'differ somewhat considerably from those of the clays and limestone above' (*op. cit.* p. 241).

As in the Spilsby Sandstone, lamellibranchs are the most abundant fossils. These are chiefly of the genera *Exogyra*, *Trigonia*, *Pecten* (including numerous individuals of the gigantic *P. cinctus*), *Cucullæa*, *Lima*, *Panopæa*, etc.[4] Many of the species occur likewise in the underlying sandstone. Brachiopoda are also numerous, especially in the Acre House section, where they seem to characterize the clayey material immediately overlying the harder rock (see section, p. 203).

The cephalopoda are represented by both ammonites and belemnites, but while the latter are of common occurrence, the former are rare and poorly preserved. All the belemnites that I have been able to observe in place in the Ironstone, whether at Nettleton Hill, Donnington, or Hundleby, have belonged to the *lateralis*-group (including *B. lateralis*, Phill., *B. russiensis*, d'Orb., and *B. sub-*

[1] Quart. Journ. Geol. Soc. vol. xxxviii. (1882) p. 243.

[2] A. J. Jukes-Browne, *ibid.* vol. xlix. (1893) pp. 467 & 472.

[3] Messrs Dikes and Lee's description of the deposit is as follows:—'A mass of small, globular, shining grains, of a dark brown colour, cemented together by ferruginous matter; it occurs in the higher part of the bed [green sand and sandstone] nearly at its junction with the grey stone; and, possibly, ought to have been classed with it,' Mag. Nat. Hist. ser. 2. vol. i. (1837) p. 565.

[4] Prof. Pavlow (*op. cit.*) has recently recognized among these *Aucella Keyserlingi*, Lahus., a form well known in Russia.

quadratus, Roem.). But from the spoil-heaps of the abandoned mines near Acre House I have also obtained a few fragments of *B. jaculum*, along with two pieces of *Ammonites* (*Hoplites*) cf. *regalis* (*noricus* of Judd) and a fragment of *Olcostephanus*, near *Astierianus*, d'Orb., which appear to have been embedded in a matrix of clay with ironstone-grains.

The ammonites collected, with the above exception, are all deep-whorled *Olcostephani* (subgenus *Polyptychites* of Pavlow), including *Olcostephanus* (*Polyptychites*) *Blaki*, Pavl.; *O.* (*P.*) *Beani*, Pavl.; and *O.* (*P.*) cf. *ramulicosta*, Pavl.; which are all species characterizing the upper part of the 'Zone of *Belemnites lateralis*' at Speeton.

These cephalopoda alone are sufficient to fix the correlation with the Speeton section, and their evidence is confirmed by several other fossils common to the two areas; among others being *Exogyra sinuata*, var. (a well-marked form which I think should rank as a separate species), *Astarte senecta*, Bean MS., *Pholadomya*, sp., *Arca*, sp., etc. Many of the lamellibranchs, however, such as the *Trigoniæ*, *Cucullææ*, etc., and some of the brachiopods, which abound in the Claxby Ironstone and the Spilsby Sandstone, have not been found in the Speeton Clay, while other fossils, like certain species of *Lingula*, *Nucula*, etc. which are plentiful at Speeton do not occur in Lincolnshire. This differentiation of the contemporary faunas is evidently the outcome of the different conditions of depth, nature of sea-bottom, etc., prevalent in the two areas; and their mutually complementary character at these and other horizons will prove of the greatest value when the palæontology of the whole series comes to be exhaustively studied.

The Claxby Ironstone as developed at Acre House and Donnington may then be regarded as equivalent to the beds D 1 to D 4, forming the upper part of the 'Zone of *Belemnites lateralis*' in the Speeton section; and the presence of the precursors of a change of the fauna in its topmost clayey layer brings the stratum into the closest agreement with the Yorkshire beds, where we find the same indications at this horizon in the Compound-Nodule Band, D 1.

From this correlation it follows that the palæontological affinity of the deposit is altogether with the underlying Spilsby Sandstone, although stratigraphically it seems to be more closely connected with the overlying Tealby Clay. At Nettleton Hill it is clear that the ironstone and associated ferruginous clay extend quite to the top of the zone of *Belemnites lateralis*. That the striped clay immediately overlying it contains a different fauna is well shown by the following section, recently exposed by a slip in an old quarry, at the second fence south of the old mine-buildings near Acre House:—

Section exposed by a slip in the quarried escarpment south of Acre House Mine.

		Feet seen.
Tealby Clay.	Striped pale and dark blue clay, slightly loamy, with pale brown nodules with dark pyritous interior. *Belemnites jaculum* (rather plentiful), *Exogyra sinuata* (large typical form), and other (undetermined) shells .... about	10
Claxby Iron-stone.	Clay crowded with oolitic ferruginous grains. *B. lateralis* (abundant); many brachiopods ...... about	1
	Slightly gritty oolitic ferruginous rubbly rock, crowded with fossils. *B. lateralis*, *Pecten cinctus*, *Exogyra sinuata* (small angular variety), etc. .... about	7
Spilsby Sandst.	Coarse greyish sand, indurated at the top, soft and incoherent below. *B. lateralis*, and casts of shells ... about	12

In the lower part of the Tealby Clay in this locality I have not been able to find any ammonites or other discriminative fossils except *Belemnites jaculum*, and am therefore unable to decide what portion of the extensive zone of *B. jaculum* is represented; but from the presence, at a slightly higher level, of forms which at Speeton make their first appearance 50 or 60 feet above the base of the zone, and from the absence of some characteristic species of the '*noricus*-beds' (C 9, 10, & 11), I am inclined to think that not only in this section but throughout Lincolnshire the lower portion of the zone is absent, except for that small portion of it which may be represented by the clayey band forming the top of the Ironstone.

The unfortunate absence of sections prevents an accurate demarcation of the upward range of *Belemnites lateralis* farther south in Lincolnshire; though at Donnington, as at Nettleton, its limit must be at or about the top of the Ironstone, at which horizon H. Keeping[1] records *Amm. noricus* (*Hopl. regalis*). At any rate, the pit in Tealby Clay at the brickyard adjoining the railway-station there, which seems to be very little above the top of the Ironstone, yields no other belemnites except *jaculum*; while the ammonites, *Olcostephanus* (*Simbirskites*) *umbonatus*, Lahus., and cf. *Payeri*,[2] Toula, and other fossils found in it show that the horizon is at least midway up in the Zone of *B. jaculum* (see p. 207). Nor, so far as the scanty evidence tells, is there anywhere south of this place any indication of *B. lateralis* in the clays above the Spilsby Sandstone until we reach the southern extremity of the escarpment, where just before the series disappears beneath the superficial deposits of the Fenland, we find an important modification of the conditions.

In this neighbourhood, from 1 to 2 miles west of Spilsby, there are outliers of clay on the Spilsby Sandstone, which at Hundleby, and again at Marden Hill near East Keal, have been extensively dug for brick-making. These clays have always been mapped and recognized as part of the Tealby Clay, and must indeed originally have been conterminous with that deposit; yet they contain *B. lateralis* and its accompanying fauna, from bottom to

[1] Quart. Journ. Geol. Soc. vol. xxxviii. (1882) p. 242.
[2] See note, p. 207.

top as far as exposed, and must therefore be considered along with the Spilsby Sandstone and the Claxby Ironstone as forming, for palæontological purposes, the 'Zone of *Belemnites lateralis*.' The sections afforded by these pits are as follows :—

Section at the western end of Hundleby Brickyard.

	Feet.
Ferruginous gritty clay, partly indurated and nodular, with a few obscure fossils; rather like the Carstone in appearance.	3
Striped gritty clay	4
Band of irregular, round, brown, ferruginous nodules. *Ammonites*, cf. *gravesiformis*, etc.	
Striped pale- and dark-blue gritty clay	5
Band of large pale-brown nodules.	
Blue pyritous clay with pale sandy streaks, and flat pyritous nodules full of coarse grit. *Belemnites lateralis*; small crushed ammonites; wood perforated by boring-shells, etc..	5

Section at the south-western corner of Marden Hill (East Keal) Brickyard.

	Feet.
Red clayey soil and drift, with fragments of chalk and flint. about	3
Weathered banded clay, brown, pyritous, and silty, with slightly ferruginous layers and sandy streaks, and a gritty seam at the base ...... about	4
Silty blue clay with sandy streaks and ferruginous layers	5
Fossiliferous seam, with *Belemnites lateralis*, small crushed ammonites (*Olcostephanus*), and many small univalve and bivalve shells.	
Clay as above, rather more gritty, with coarse grit-grains in flat pyritous nodules. *B. lateralis* and other fossils as above, in places......	17
Floor of lumpy ferruginous stone, like coalescent nodules, slightly gritty, and full of oolitic ferruginous grains. Many casts of fossils. *Ammonites* (*Olcostephanus*), cf. *gravesiformis*, etc., *Trigonia*, *Astarte*, etc.	

The fossils of these pits are practically identical. At Hundleby, though the unworked condition of the section at the time of my examination of it, in 1893 and again in 1895, was unfavourable for collecting fossils in place, I found fragments of *Belemnites lateralis* scattered in all parts of the pit, unmixed with any other form of the genus. I found also clay-stone casts of the deep umbilicus of 'coronated' ammonites akin to *Olcostephanus* (*Polyptychites*) *gravesiformis*, Pavl. (= *Ammonites Irius*, d'Orb., of Judd), exactly as they occur in bed D 3 at Speeton, together with some smaller specimens of the same group, *O.* (*P.*) cf. *Keyserlingi* and cf. *gravesiformis* (which are evidently the forms referred in the Geol. Surv. Mem. to *A. speetonensis*), and several brachiopods and lamellibranchs present in the Claxby Ironstone.

At Marden Hill on my last visit the section was quite fresh in one part of the pit, and here I obtained *Belemnites lateralis* in the clay within 9 feet of the top, and at lower levels down to the base of the pit, but found no trace of any other belemnite. Small

imperfectly-preserved ammonites, very similar to those which occur abundantly in the '*Astarte*-bed' D 4 at Speeton, were rather plentiful at one horizon in the clay, and also in the ferruginous stone at the base of the pit, the species being the same as at Hundleby.

Most of the bivalves found in the other pit also occurred here: and in a silty band in the clay about halfway from the top of the section, along with some small crushed ammonites (*Olcostephani*), were numerous dwarf univalves and bivalves referable to *Dentalium*, *Cerithium* (?), *Pecten* (a Spilsby Sandstone form), *Isocardia* (?), *Astarte* cf. *senecta*, etc.

An important feature of both sections is the large admixture of coarse sand with the clay. This occurs throughout in little dabs and streaks, or in thin irregular seams tending to concentrate into shallow cakes of irregular outline, or to be caught up in the concretions of iron pyrites. In some places this sand is so coarse as to be almost pebbly, and the quartz-grains have a smooth polished surface, like the grains in the Spilsby Sandstone. Similar sandy clay associated with the Spilsby Sandstone seems to have been met with in the deep boring at Skegness, 11 miles farther east.[1] I have not found this gritty character in anything like the same degree in the Tealby Clay anywhere along its main outcrop under the Chalk escarpment.

From the Geol. Surv. Mem. ('East Lincolnshire,' pp. 14 and 22) we learn that the ferruginous stratum at the base of the Hundleby pit rests directly upon the Spilsby Sandstone, and that a well was sunk in it to a depth of 14 feet without reaching its base. The rock forming the floor of the Marden Hill pit is mentioned as being 'probably the same bed as that seen at Hundleby'; but it appears to me not unlikely that it may represent one of the higher nodular bands of the Hundleby section. The clay at Marden is rather more gritty, while at Hundleby there are bands of ferruginous concretions, in the clay above the base of the pit, which are not present at Marden, and the general field-evidence suggests that the Marden section is the higher.

In the Survey Memoir the Hundleby Ironstone is held to be the southern equivalent of the Claxby Ironstone, and the overlying clay is recognized as forming the base of the Tealby Clay. A list of the fossils of the clay is given (*op. cit.* p 142), consisting of 13 species, with 9 further cases in which the genus only is determined. It is remarked at the foot of this list that 'this assemblage is also' (*i. e.* like that of the underlying Ironstone) 'eminently Neocomian.' *Belemnites lateralis*, *Ammonites speetonensis* and *A. Gowerianus* (?) are the cephalopoda mentioned, and these by no means establish the statement, while the remaining fossils, with the exception of one brachiopod, are all lamellibranchs of doubtful value as determinatives in this case.

At any rate, these sandy clays all fall within the zone of *B. lateralis*, and, as will presently be shown, their fauna is quite

[1] Geol. Surv. Mem. 1887, 'East Lincolnshire,' p. 169, ; see also Quart. Journ. Geol. Soc. vol. xlix. (1893) p. 472.

distinct from that of the main mass of the Tealby Clay. And since we know that the Claxby Ironstone extends to the top of this *lateralis*-zone, it follows that the clays in question cannot represent a higher horizon than that deposit. These clays, with their accompanying bands of ironstone, occupy in fact the same position with regard to the Spilsby Sandstone at the southern end of the Wolds as the Claxby Ironstone farther north, and are equivalent in age.

We are thus brought face to face with an excellent example of that divergence of results which is bound to present itself sooner or later whenever the lithological and the palæontological characters of a stratified series are independently traced out over an extended area.

It cannot be denied that throughout Lincolnshire the Spilsby Sandstone and the Tealby Clay, and to some extent also the Claxby Ironstone, form well-defined stratigraphical units, which must be taken by the field geologist as the basis for his work in mapping out the structure of the country. Yet the palæontological evidence demonstrates that the boundaries of these continuous masses of like material are not strictly isochronous lines, but have had a progressive development.

It seems almost inevitable that in such cases the palæontologist and the stratigraphist must fix each his own limits independently of the other. The stratigraphist cannot well make use in the field of a line which forsakes a strongly-defined lithological junction to wander vaguely amidst a mass of uniform composition, wherein he could scarcely follow it even were there continuous sections in every direction. The palæontologist on the other hand is equally compelled to repudiate boundaries obliquely traversing time-limits and life-zones which he seeks above all things to define.

If we could study the extension of the whole series in an easterly direction, we should probably find this lateral change of lithological character even still more strongly marked. Apparently towards that quarter the various strata would merge into a clayey sequence such as we find at Speeton, as is indicated by the borings east of the Wolds. At Willoughby the full thickness of the Spilsby Sandstone was not proved, but the character of the stratum seems to have become greatly modified, being no longer a clean grit but an 'earthy sandstone' and 'ferruginous marlstone,'[1] while in the Skegness boring already referred to, the Sandstone which is about 50 feet thick in the neighbourhood of Spilsby, has thinned away to 19 feet, and is associated with clay both above and below; and the overlying clays have thickened from about 70 to 191 feet. The presence at various horizons in the clay at Speeton of thin, imper-

[1] A. J. Jukes-Browne, Quart. Journ. Geol. Soc. vol. xlix. (1893) p. 467. In this paper a somewhat different reading is given of the Skegness boring from that in the Geol. Surv. Mem. ('East Lincolnshire,' p. 168), and the thickness of the Spilsby Sandstone (including in this term some clayey material) is stated to be 26 feet. At a boring near Driby, if the record is to be trusted, only 4 feet of sand (Spilsby Sandstone) and 4 feet of ironstone (Claxby Ironstone?) was found between the Tealby Beds and the Kimeridge Clay (*ibid.* p. 155).

sistent ferruginous stone-bands,[1] probably indicates the final stages of this lateral change. Such changes are of course among the commonplaces of geology, and parallel examples might be adduced from beds of almost every age at home and abroad. Dr. J. W. Gregory has recently drawn attention to a striking example of similar conditions in the Gault and Lower Greensand of the South-east of England, and he, too, has pleaded the necessity for the recognition of two independent scales, the lithological and the chronological,—'not contradictory, but complementary, and each must be retained for its special purpose.'[2]

f. The Tealby Clay.

The available information regarding the exact age of the Tealby Clay along the major part of its course is very meagre, from the lack of clear exposures, and from the perishable character of the fossils which are largely pyritous.

Most of the sections have already been referred to, and will need very little further description. In the slope above the mine-buildings near Acre House the clays are exposed in a water-runnel and at a few other places in the same vicinity, including the slip-section already given (p. 203). The fossils noticed here are *Belemnites jaculum* in tolerable abundance, *Exogyra sinuata* (the large 'Lower Greensand' form, which is common in the beds C 4 and 5 at Speeton and differs from the allied shell occurring in the zone of *Belemnites lateralis*), *Nucula* sp. and several other small bivalves in a poor state of preservation, and some crustacean remains (*Meyeria* cf. *falcifera*, Phill.). In this locality the thickness of the Tealby Clay in the mine-shaft is stated at 40 feet.[3] In character it is a rather pale striped blue clay of fine texture, with a few small oval nodules of pale brown exterior and darker interior, which frequently contain fragments of crustaceans. This deposit, in its close lithological correspondence with its equivalent horizon at Speeton, stands alone among the members of the Lincolnshire succession.

Southward from Nettleton Hill I found no place, where the fauna of the clay could be studied, nearer than the pit at Donnington Station, mentioned on a previous page. The only other fossils which I have found here besides *Belemnites jaculum* (which is abundant) and *Olcostephanus* (*Simbirskites*) *umbonatus*, Lahus., are *Exogyra sinuata* (as above), *Pecten* sp., and other ill-preserved shells, *Serpula* sp., and *Meyeria* cf. *falcifera* (abundant). In the Geol. Surv. Mem., *Ammonites speetonensis* vars. *venustus* and *concinnus*[4], *Crioceras Duvalii*, and *Perna Mulleti* are also recorded from this place.

[1] See 'Subdivisions of the Speeton Clay,' Quart. Journ. Geol. Soc. vol. xlv. (1889) p. 594, and sections, figs. 4 & 5.

[2] 'On a Collection of Fossils from the Lower Greensand of Great Chart, in Kent,' Geol. Mag. 1895, p. 103.

[3] J. W. Judd, Quart. Journ. Geol. Soc. vol. xxvi. (1870) p. 331.

[4] The specimens under this name are very near to, if not identical with, the form from my Speeton collection figured by Pavlow in 'Argiles de Speeton,' pl. xviii. (xi.) fig. 1, as *Olcostephanus* (*Simbirskites*) *Payeri*, Toula, a species founded on specimens from the Island of Kuhn, off the coast of Greenland (see Toula, 'Geologie Ost-Grönlands,' p. 498).

After this there is again a space of 8 miles in which, though the clay can be seen in places, no opportunity is afforded for obtaining fossils from it. Some old clay-pits about a mile to the eastward of Tetford are then reached, from the weathering slopes of which I have collected fragments of *Belemnites jaculum* in numbers, along with *Meyeria ornata*, Phill., *Exogyra sinuata* (as before), *Pecten* (probably *cinctus*), *Isocardia angulata*, Phill., and *Trochus pulcherrimus*? Fine selenite-crystals up to $1\frac{1}{2}$ inch in diameter are also abundant. In general character the clay resembles that of Donnington and Acre House. The above-mentioned fossils are all Speeton species, and indicate that the horizon of this pit likewise is about midway in the 'Zone of *Belemnites jaculum*.' Yet the field-evidence shows that the pit cannot be far above the base of the Tealby Clay, which seems here to rest directly on the Spilsby Sandstone, the Claxby Ironstone apparently not being represented in this neighbourhood; and the absence of the lower part of the 'Zone of *Belemnites jaculum*' is thus once more indicated.

About $1\frac{1}{2}$ mile farther south-east I found *Belemnites jaculum* washed out of the clay by a little stream running down the hill at South Ormsby; but in the remaining 6 miles between this locality and the southern termination of the Wolds at Spilsby no further fossil evidence was forthcoming. In the outliers to the westward of Spilsby, as has already been shown, the clays are of a different age and type.

So far therefore as the Tealby Clay under the Chalk escarpment can be examined, one stage only is represented, this being the middle and perhaps the upper portion of the 'Zone of *Belemnites jaculum*' (beds C 2 or 3 to C 5 or 6) of the Speeton Clay; while the rich fauna of the *Ammonites noricus* (*regalis*)-beds, which tenants 20 to 30 feet of clay in the lower part of this zone in Yorkshire, is not in Lincolnshire revealed in any visible section, except so far as its lowermost portion may be condensed in the uppermost clayey layer of the Claxby and Donnington Ironstone.

But the great expansion of these clays towards the east, which is a marked feature along the outcrop,[1] and is still better revealed in well-borings east of the Wolds at Alford, Willoughby, and Skegness, indicates that, as already hinted, the deposit almost certainly encroaches on both lower and higher zones in its prolongation in that direction, and gradually replaces, in part or wholly, the Spilsby Sandstone, the Claxby Ironstone, and the Tealby Limestone. Its greater thickness is therefore probably due, not so much to the thickening of the individual beds exposed at the outcrop, as to the incoming of higher and lower argillaceous deposits slightly different in lithological character and almost entirely different in fauna.

Under these conditions we may safely surmise that eastward, under the bed of the North Sea, the whole series merges into the

[1] A. Strahan, Quart. Journ. Geol. Soc. vol. xlii. (1886) p. 488, and Geol. Surv. Mem. 1888, 'Country around Lincoln,' p. 96.

clayey sequence whose fringe is so conveniently revealed to us in the coast-section at Speeton. Westward and southward, on the other hand, it is very probable that the clays diminish, until the sands of the underlying and overlying horizons unite and become indistinguishable.[1]

g. The Tealby Limestone (with the Upper Clay and 'Roach').

I have not devoted so much time in the field to the strata overlying the Tealby Clay as to those below that horizon, mainly because while their general correlation is readily arrived at, a more detailed comparison is rendered difficult by the still incomplete state of our information regarding the upper division of the Speeton Clay. Sufficient has been done, however, to demonstrate the relationship of these rocks to the rest of the section, and to improve our knowledge of their palæontology.

The hard calcareous bands with variable clay partings capping the Tealby Clay, known as the 'Greystone' or 'Tealby Limestone,' form a prominent feature in the stratigraphy between Caistor and Donnington, but are not definitely recognizable farther northward or southward, nor have any continuous hard beds been revealed at this horizon by the borings east of the Wolds. These facts, together with the thin and irregular character of the courses and the extent to which they are interbedded with, and in places overlain by, shaly or clayey material, suggest that the limestone is merely a locally calcareous modification of the upper portion of the Tealby Clay. It is therefore rather surprising to find how greatly the fauna differs from the known fauna of the Tealby Clay.

The limestone is best exposed in the numerous shallow pits between Normanby and North Willingham.[2] Fossils are everywhere present, but are not easy to extract; and there seems to be some difference in the species occurring in the different sections. The belemnites again supply the most definite information. They are frequently abundant, especially in the shaly partings, and are all recognizable as well-known Speeton forms occurring in the 'Zone of *Belemnites brunsvicensis*' (B), namely, *B. brunsvicensis*, Stromb., *B. speetonensis*, Pavl., and *B. Jasikowi*, Lahus. No other species have been found, and the record of *B. lateralis* from this horizon by Prof. Judd and the Geological Survey was evidently due to the confusion in the determination mentioned on a previous page.

Ammonites are rarer, the only serviceable specimens that I have myself discovered being found in the higher pit on the north side of the high road, east of North Willingham. These belong to the large

[1] For the discussion of this point see A. Strahan, 'On the Lincolnshire Carstone,' Quart. Journ. Geol. Soc. vol. xlii. (1886) p. 491.

[2] In this locality the limestone-bands occasionally enfold phosphatic and pyritous concretions, just as the large limestone-nodules of the 'Compound-Nodule Band,' D1, of Speeton enclose similar earlier concretions.

clypeiform species usually recorded as *Ammonites clypeiformis*, d'Orb.,[1] examples of which under this name are preserved in most of our public collections of Lincolnshire fossils; but I do not think that this determination can be sustained. It is only in its adult stages that the ammonite assumes its sharply-keeled discoidal form and smooth sides, since the inner whorls present a rounded back and a few continuous ribs, the fossil at this stage being very near to, if not identical with, *Ammonites Carteroni*, d'Orb. It is possible that the young forms of this ammonite may occur at Speeton, but I have not seen an adult specimen there.

Among the other and more abundant fossils are *Pecten* (several species), *Exogyra sinuata* (the Tealby Clay form), *Ostrea frons*, Park. (plentiful here, but very rare at Speeton), *Lima*, *Pholadomya*, and many other lamellibranchs, with some brachiopods, etc. Several of the above occur at the equivalent horizon at Speeton, but their relative abundance in the two areas is very different.

Pecten cinctus is often very plentiful and of large dimensions, but I think that it displays characters of varietal, or even of specific value, differentiating it from the similar fossil of the Claxby Ironstone and Spilsby Sandstone. In the last-mentioned stratum the dwarfed representatives of the species can scarcely be distinguished from *P. lamellosus*, Sow., of the Portlandian, and when the fossil is studied throughout its extended range it will probably furnish the palæontologist with another illustration of a slowly-changing species, with all the usual difficulties, to which I suppose that he will in time become accustomed. Under present conditions the species is, as I pointed out in my former paper, of very little value as a zonal fossil.

The evidence of the fauna, then, suffices to enable us to recognize in the Tealby Limestone, as developed in the above-mentioned area, some portion of the 'Zone of *Bel. brunsvicensis*' (B) of the Speeton section; and the presence in Yorkshire in the clays of this horizon of a considerable amount of calcareous matter, which takes the form of bands of thickly-set septarian nodules of large size ('Cement Beds' of Judd), indicates that the deposition of more or less calcareous sediment was common to both districts at this stage.

The evidence is insufficient to demonstrate exactly how much of this extensive zone is represented by the Tealby Limestone, but it seems probable that if we could have complete sections we should find *Belemnites brunsvicensis* extending slightly below the base of the limestone in most localities, and also stretching upward at least as far as the lowest part of the Carstone.

Regarding the 'Roach Ironstone and Clay' which underlie the Carstone farther south, and are by the Geological Survey considered to be the southerly equivalents of the Tealby Limestone, I have no new information whatever to bring forward. Such scanty exposures of these deposits as I could find were unfossiliferous, and therefore practically useless for my purpose.

[1] J. W. Judd, Quart. Journ. Geol. Soc. vol. xxiv. (1868) p. 246; list reproduced in Geol. Surv. Mem. 1888, 'Country around Lincoln,' p. 103.

h. The Carstone.

The lithological characters and stratigraphical relations of the pebbly ferruginous sand which in Lincolnshire overlies the deposits above described, and extends upward to the Red Chalk, have been carefully set forth in the Survey Memoirs[1] and in Mr. A. Strahan's excellent paper on the subject in this Journal.[2] Except in the layer immediately below the Red Chalk, where *Belemnites minimus* and *Terebratula biplicata* are found, fossils are of very rare occurrence in it. Such as have been discovered are contained in eroded phosphatic nodules, and are supposed to have been derived from lower strata which have been destroyed.

The species recorded[3] are: *Ammonites spectonensis*?; *A. plicomphalus*? and *Lucina*? from a nodule-bed at its base near Otby; and *A. Deshayesii*, *A. triplex*, *Requienia*?, *Astarte*, *Corbula*, *Modiola*, *Myacites*, *Pholadomya*, *Cyprina*, and *Teredo*, from Claxby.

Not having myself succeeded in finding any of these fossils in the deposit, I have been unable to investigate their mode of occurrence and the character of the supposed 'pebbles' with which they are associated, and therefore am not in a position to discuss their origin. But from the nature of the list and the general features of the nodules in the stratum, I am inclined to consider their derivative nature not proven. At any rate, *Ammonites Deshayesii* is not far from its proper horizon, and, as already stated (p. 198), I am satisfied that where this species occurs in the Carstone at Hunstanton it is not derivative, but in place. The other ammonites mentioned, being all uncertain species, are of slight account in the discussion, while the remaining determinations of the list are too incomplete to afford any information.

As regards the stratigraphical relations of the deposit, I can corroborate Mr. Strahan's account of its upward passage into the Red Chalk, and the presence of *Belemnites minimus* in it just below the junction. In the southern part of its outcrop the Carstone has a thickness of about 40 feet, but northward it thins away, until in the last sections seen before reaching the Humber it remains only as a pebbly base to the Red Chalk. Both phenomena are exactly reproduced, as shown in an earlier part of this paper, by the ferruginous sands exposed in a few places along the western edge of the Yorkshire Wolds, which are no doubt the northern equivalents of the Carstone. And as it has been also shown that these Yorkshire sands can be correlated with much probability with the 'Passage-marls with *Belemnites minimus*' (A) of Specton and Knapton (which, it may be noted, contain at the first-mentioned place 'lydites' and other small gritty particles), it follows that the same correlation must be

[1] 'Country around Lincoln,' pp. 105 *et seqq.*; 'East Lincolnshire,' pp. 23 *et seqq.*

[2] 'On the Lincolnshire Carstone,' Quart. Journ. Geol. Soc. vol. xlii. (1886) p. 486.

[3] *Ibid.* p. 488; the Claxby list was supplied to Mr. Strahan by Mr. H. Keeping.

applied to the Lincolnshire Carstone. But if *Hoplites Deshayesii* be in place in Lincolnshire as in Norfolk, it would appear that where the Carstone is fully developed its lower portion must lie within the 'Zone of *Belemnites brunsvicensis*,' in which event the interval between it and the Tealby Limestone cannot be great.

Indeed under any circumstances, if I am right in thinking that no break exists at Speeton between the 'Passage-marls' and the clays containing *B. brunsvicensis*, *Hoplites Deshayesii*, and *Amaltheus bicurvatus*, any unconformability which may exist at the base of the Carstone, as supposed by Mr. Strahan, must possess a relatively small time-value where that deposit overlies the Tealby Limestone Series, since on comparison of this part of the Lincolnshire sequence with that of Speeton there is seen to be little or nothing lacking.

At the upper boundary of the deposit it is very probable that there may be in some degree a lateral as well as a vertical passage into the Red Chalk. That the accumulation of sand in the shallower or more exposed areas probably continued for some little time after the deposition of the chalky sediment had commenced in adjacent regions is, I think, directly suggested by the evidence made known to us by Mr. W. Hill in his careful study of the lower beds of the Upper Cretaceous rocks.[1] With the Red Chalk commenced that period of slow depression, which in its later stages brought back once more an uniformity of conditions over the eastern part of England which had not existed since Kimeridgian times. This depression swept away the more local influences which had hitherto prevailed in South Yorkshire and North Lincolnshire, where a belt of country had been slowly brought up within reach of the denuding agencies and gradually planed down. South and east of the elevated area, even where the marine conditions were continuous, the proximity of land and the gradual change in its outline affected from time to time the factors which govern the accumulation of sediments, so that in Mid-Lincolnshire the deposits of this period are marked by their local and changeful characters.

V. Statement of the Correlation.

The result of this investigation is to show that in Lincolnshire, as in Yorkshire, the various species of belemnites present in the rocks afford the most natural and convenient means for classifying the strata; but that the well-defined zones which they form do not always coincide with the lithological divisions.

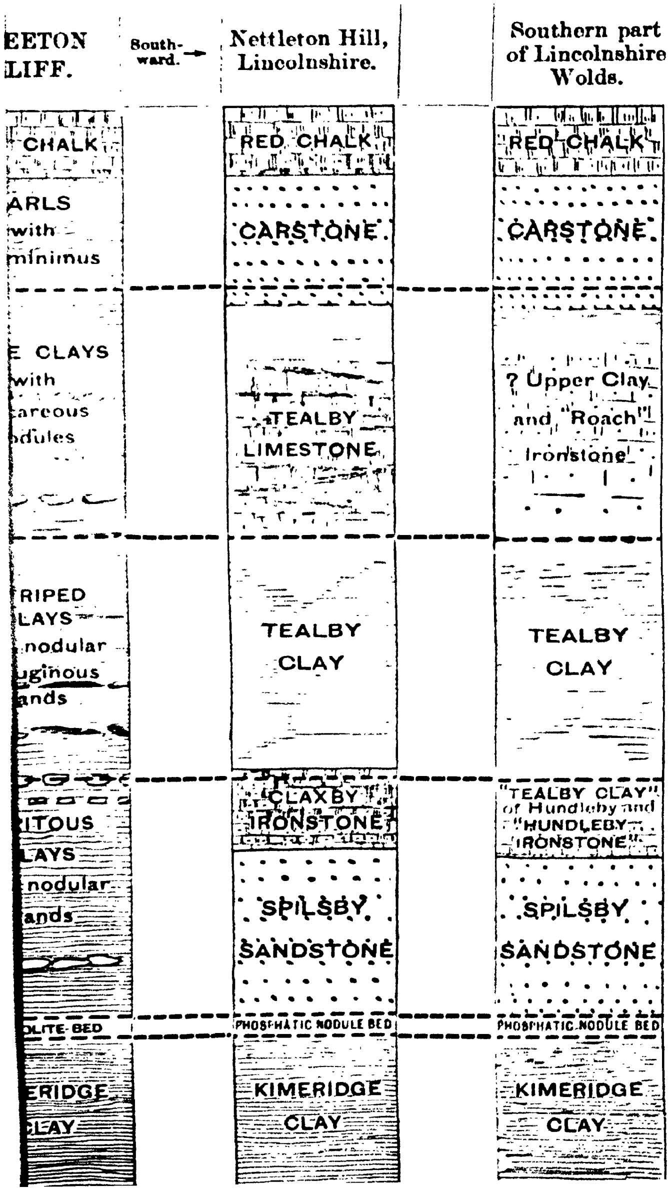
Of these zones, that of *Belemnites lateralis* appears to be quite as fully represented in Lincolnshire as at Speeton. The 'Zone of *Belemnites jaculum*,' which occupies so large a proportion of the Speeton Clay, is in most of the Lincolnshire sections condensed into narrow limits, and may be in part unrepresented.

The 'Zone of *Belemnites brunsvicensis*' is well exhibited, but from the unfossiliferous character of some of the sediments and the lack of

[1] Quart. Journ. Geol. Soc. vol. xliv. (1888) p. 320.

[To face p. 212.

... IN YORKSHIRE AND LINCOLNSHIRE.



clear sections, only the broader features of its relationship can be demonstrated.

In both areas the uppermost beds of the series pass upward into the Red Chalk.

The correlation of the typical sections of each district is illustrated in the diagram facing the opposite page.

VI. The Age of the *Belemnites lateralis* Beds.

The definite purpose of my paper was to bring out anew, and to place on a more satisfactory basis, the relationship of the strata underlying the Chalk in Yorkshire and Lincolnshire, and I venture to hope that in the preceding pages this has been accomplished. As for the broader issues to which this work gives rise, I think they may for the most part await with advantage the accumulation of fuller and more accurate information on many points. In England there is still much to be done, both in the study of the palæontological material already collected, and in the re-examination, in the light of the new evidence, of the region lying to the southward of that herein discussed. In the Eastern Midlands at least some portion of the fauna of the Speeton Series (including *Belemnites* (*lateralis*) *subquadratus*) is preserved in some of the phosphatic-nodule beds, but whether in an original or derivative form is still uncertain. In several regions abroad also, and especially in Germany, the information which we possess regarding the corresponding strata is at present conflicting and insufficient, and will undoubtedly be considerably affected by researches which are now in progress. I had indeed hoped that my esteemed friend Prof. Pavlow would have been able to lay before the Society on this occasion a *résumé* of the available facts respecting the Continental equivalents of the series. But Prof. Pavlow has at the last moment, from physical indisposition, found it impossible to complete his notes in time. We may hope, however, that he will shortly be able to bring forward his valuable contribution on the subject.[1] Meanwhile I think that a brief recapitulation of the work already published, bearing on the disputed question of the age of the Zone of *Belemnites lateralis*, will form a fitting conclusion to this paper.

Leckenby seems to have been the first definitely to formulate the view that the lowest part of the Speeton Clay should be classed as Jurassic, basing his opinion mainly on the occurrence therein of coronated ammonites of the *Gravesianus*-type.[2] These ammonites were afterwards supposed by Prof. Judd to have been obtained from beds capping the Upper Kimeridge shale, but below the clays with *Belemnites lateralis*.[3] In my former paper, however, I was

[1] [While this paper was passing through the press, the communication of Prof. Pavlow above referred to, 'On the Classification of the Strata between the Kimeridgian and Aptian,' was read, and its publication may be looked for in a subsequent number of the Journal.—April 22nd, 1896.]

[2] See note by J. Leckenby in Dr. T. Wright's Monogr. 'Brit. Cret. Echinod.,' Pal. Soc. vol. xxi. pt. i. p. 9.

[3] 'On the Speeton Clay,' Quart. Journ. Geol. Soc. vol. xxiv. (1868) p. 228.

able to prove that the true horizon of these fossils was the upper part of the Zone of *Belemnites lateralis*. Hence, if these ammonites were sufficient to demonstrate the Portlandian age of the rocks containing them, the line between Jurassic and Cretaceous in the Speeton section must, I urged, be drawn at the top of this zone, as Leckenby proposed, and not at its base, as Prof. Judd had suggested.

Meanwhile the subject had been attacked from an entirely different standpoint by the Russian geologists M. Serge Nikitin (of the Russian Geological Survey) and Prof. A. Pavlow (Moscow University), who had attended the meeting of the International Geological Congress in London in 1888, and had taken the opportunity then afforded of studying the Speeton section and its fauna upon the spot. These gentlemen soon afterwards published independent readings of the section and its correlation,[1] differing in some important points, but agreeing in recognizing in the Zone of *Belemnites lateralis* the equivalent of the 'Upper Volga Beds' of Central Russia and the Purbeck of the South of England. Nikitin however considered that the ammonites afforded no evidence of the Jurassic age of the beds, since they had been incorrectly determined, and belonged in reality to species recognized as Neocomian in Germany.[2] He was thereby confirmed in his previously-expressed opinion that the Upper and Lower Volga Beds of Russia (and presumably also their English equivalents) should be regarded neither as Jurassic nor Cretaceous, but strictly as passage-beds between these systems. Pavlow, on the other hand, thought that a stricter definition was possible, especially as he regarded the Zone of *Belemnites lateralis* as equivalent not only to the Purbeck, but also to the Portland Stone of the South of England.

In a later memoir[3] (to which I had the honour of contributing a chapter respecting the stratigraphy of the deposits in the North of England) Prof. Pavlow, continuing to work on the same general lines, extends his study of the subject to embrace the whole of the North European area, and shows that the cephalopoda of these rocks confirm in most points his former conclusions. He finds a certain amount of difference between the fauna of the upper and the lower portions of the Zone of *Belemnites lateralis*, which enables him to divide it into two parts characterized by different types of ammonites (in the same manner as the Zone of *B. jaculum* is

[1] S. Nikitin, 'Quelques Excursions dans les Musées et dans les Terrains Mésozoiques de l'Europe occidentale,' Bull. Soc. Belge de Géologie, vol. iii. Mém. pp. 29–58 (1889); A. Pavlow, 'Études sur le Jurassique supérieur et le Crétacé inférieur,' Bull. Soc. Imp. Naturalistes de Moscou,' n. s. vol. iii. (1889) p. 61.

[2] The German evidence becomes here of extreme importance, and I am very glad to learn that the whole question is now being carefully re-studied in that country. If the German equivalent of the zone of *Belemnites lateralis* has been considered Neocomian only on the strength of the old Speeton correlation, no argument could be safely deduced from this quarter. But from its geographical position the succession in Germany will probably eventually be found comparable with several surrounding areas, and thus the linking together of the outlying regions will be more securely done than is at present possible.

[3] 'Argiles de Speeton,' Moscow, 1891–1892.

divided), the lower being tenanted by *Olcostephanus* (*Craspedites*) *subditus* and allies, and the upper by *O.* (*Polyptychites*) *gravesiformis* and allies. These together form the 'série Spectono-russe' (p. 174), which he shows to be equivalent to the Upper Portlandian (Purbeck and Portland Stone) of the South of England, and he proposed to designate these rocks the 'sous-étage Aquilonien' (p. 192). He then discusses exhaustively the correlation of this 'Aquilonian sub-stage' throughout Europe, and shows that everywhere in Southern as well as in Northern Europe the equivalents of this sub-stage underlie the 'étage Néocomien inférieur,' which upon various considerations is declared the true base of the Lower Cretaceous system. He further urges in favour of this grouping that it agrees best with the older definitions and traditions of the science, and concludes his argument thus:—'Si nous replaçons l'ancienne limite entre les deux systèmes nous nous privons d'une limite très nette, paléontologiquement très bien définie, et qui, grâce à la transgression remarquable de la faune méridionale vers le Nord, peut-être observée dans une vaste région, circonstance qui nous fait considérer cette limite comme très heureusement choisie par les coryphées de la science et comme très précieuse au point de vue de la stratigraphie comparée. Cette limite a été tracée par la nature même comme une limite ayant fixé l'époque d'un évènement géologique remarquable, savoir la disparition d'une partie considérable du continent portlandien et le commencement de la migration de la faune méridionale vers le Nord, et réciproquement peut-être.' ('Argiles de Speeton,' sep. cop. p. 199.)

But to establish this classification it became necessary to carry down into the Jurassic system not only the whole of the Berriasien of South-eastern France, but also the so-called Wealden and the Hils Conglomerate of North-western Germany, and in doing this Pavlow is at variance with the opinions of several geologists of the Continent, so that the subject must be considered as still under discussion. Indeed, in a later paper, 'On the Mesozoic Rocks of the province of Riasan, Russia' (Moscow, 1894),[1] if I rightly understand the brief final *résumé* in French, Prof. Pavlow seems inclined to grant that recent discoveries have shown that the 'Petchorian sub-stage,' capping the 'Aquilonian,' with *Olcostephanus stenomphalus* in the lower part and *Polyptychites Keyserlingi* in the upper portion, may in that region correspond to the Lower Neocomian of Central Europe. In his forthcoming notes on the subject Prof. Pavlow will no doubt discuss this new evidence, and show its exact bearing on the question at issue.

So far as the classification of the English strata is concerned, it must, I think, be admitted that the limit of the Lower Cretaceous and Jurassic systems is more or less arbitrary and conventional, often without reality in the field, and is therefore to be treated on a basis of general convenience and historical priority.[2] And this

[1] Scient. Mem. (Utcheniva Zapiski) Imp. Univers. Moscow, vol. xi. p. 1.

[2] See H. B. Woodward, Geol. Surv. Mem. 'Jurassic Rocks of Britain,' vol. v. p. 3.

state of affairs prevails, as the above discussion has indicated, not in England only, but throughout the greater part of Europe, and also in North America. Under such conditions there must necessarily be much discussion and interchange of views before a boundary of general application can be agreed upon. Nor is this at all attainable except by some sacrifice in matters of local convenience.

Thus, in the North of England there is no doubt that in spite of the early-recognized and oft-discussed Jurassic affinities of the Spilsby Sandstone fauna,[1] the field-geologist working independently in that district would find the base of that deposit to afford by far the most suitable line of demarcation between the systems. It is a strongly-defined horizon, marking the termination of a period of quiet and uniform sedimentation over the whole region, while above it, owing to more local and less stable conditions, the character of the accumulation frequently alters horizontally as well as vertically, thereby rendering the tracing-out of a synchronal line a matter of extreme difficulty. Yet it seems inevitable that, in spite of its convenience, this line will have to be abandoned whenever the wider bearings of the stratigraphy of the region are in question, unless we are prepared to advocate extensive alterations in other areas to suit it. If, on the other hand, we take the upper boundary of the *lateralis*-zone as our line of division, we find that though in Yorkshire, as Leckenby pointed out, this horizon is lithologically well defined, in Lincolnshire, as already shown, in the southern part of its course it is purely palæontological and scarcely traceable on the ground.

The division of the Zone of *Belemnites lateralis* into two portions by means of the ammonites, as proposed by Pavlow, suggests the possibility of an alternative course, by which the lower part with *Ammonites subditus*, corresponding to the major portion of the Spilsby Sandstone and presumably to Beds D 5 to D 8 of Speeton, might be separated from the rest of the zone, in which occur the '*gravesiform*' ammonites, and the one classed as Jurassic and the other as Cretaceous. [This scheme is powerfully advocated by Prof. Pavlow in his recent contribution to the Society.] But while this plan would possibly satisfy some of the objections which have been raised to the inclusion of the whole zone in the Jurassic, it appears to me that the life-forms other than the cephalopoda common to the two parts of the zone will, when fully worked out, be found so numerous that a line drawn at this horizon would in England be both palæontologically and stratigraphically weak, without serving the general European convenience better than before.

[1] Prof. H. G. Seeley, in the discussion on J. F. Blake's 'Portland Rocks of England,' Quart. Journ. Geol. Soc. vol. xxxvi. (1880) p. 236, and in several earlier discussions on similar subjects.

Mr. G. Sharman, in Geol. Surv. Mem. 1887, 'East Lincolnshire,' p. 141, in discussing the fossils, remarks:—'It is tolerably evident, therefore, that these calcareous concretions (of the Spilsby Sandstone) occupy a lower horizon than any Neocomian beds hitherto described, and, in so far as palæontological evidence goes, seem to occupy an intermediate position between the lowest Neocomian and the uppermost Oolites.'

However, where so much uncertainty still exists, it appears to me that, pending the accumulation of further evidence, we shall scarcely be justified in pronouncing on one side or the other a final decision in this matter. Even with regard to the rocks of this age in the South of England, on the classification of which the whole of this discussion hinges, there is still much obscurity. It seems now to be very generally acknowledged that there is a passage from Purbeck to Wealden where both are fully developed[1]; and recently even the strength of the evidence on which the Wealden itself is classed as Cretaceous has been challenged, and the chief elements of its fauna declared by several authorities to be Jurassic rather than Cretaceous in their affinities.[2]

It appears, in short, to be the fact that while over Western Europe there is usually a distinct stratigraphical break at the base of the Upper Cretaceous, as Mr. Strahan and others have frequently pointed out,[3] the base of the Lower Cretaceous, as at present recognized, whether the sequence be freshwater or marine, presents no such break, but a more or less gradual passage both in character of deposit and in fauna. Under such conditions it is mainly a question of general convenience what particular horizon shall be taken as the boundary of the systems, and the essential determinative must rest in the agreement of competent opinion.

VII. Concluding Summary.

The leading conclusions of this paper may be epitomized as follows:—

1. Further work on the Speeton section, while extending our knowledge of the palæontological details, has fully sustained the results of the author's previous investigations.
2. The evidence at present available is insufficient to demonstrate the exact conditions which bring about the rapid attenuation and final disappearance of the Speeton Series in a westerly direction in Yorkshire. Contrary to the accepted view, however, the lower zones are probably the first to die out, and are overstepped or overlapped westward by the higher divisions, since at Knapton, 14 miles inland, only the upper zones of the coast-section can be proved to occur, as shown by the presence of the marls with *Belemnites minimus* passing upward into the Red Chalk, and by the fossils in the old collections, including *Hoplites Deshayesii*, under the name of *Ammonites knaptonensis*, Bean MS., and a few others of the same zone.

[1] See H. B. Woodward in Mem. Geol. Surv. 'Jurassic Rocks of Britain,' vol. v. pp. 3 and 243 *et seqq.* (with good bibliography).

[2] O. C. Marsh, Geol. Mag. 1896, p. 8; [also in 'Nature,' vol. liii. (1896), p. 436, as regards the reptiles; A. S. Woodward, Geol. Mag. 1896, p. 70, as regards the fishes; and A. C. Seward, in 'Nature,' vol. liii. (1896) p. 462, as regards the plants].

[3] See, among others, A. Strahan's recent paper 'On Overthrusts of Tertiary date in Dorset,' Quart. Journ. Geol. Soc. vol. li. (1895) p. 561.

3. The ferruginous sands which occur locally beneath the Red Chalk on the western edge of the Yorkshire Wolds are recognized as agreeing in all respects with the Lincolnshire Carstone, and where absent are to some extent represented by a pebbly base to the Red Chalk, as in Lincolnshire. In both counties Mr. A. Strahan's conclusions as to the relations of the Carstone to the Red Chalk are confirmed.
4. In Mid-Lincolnshire all the palæontological zones of the Speeton Series are identified and traced: and though their lithological aspect is greatly modified, and is accompanied by a corresponding modification of their fauna, the presence of the leading zonal types of the cephalopoda readily establishes the general correlation proposed by Prof. Pavlow and the author, which differs in many respects from that adopted by previous investigators.
5. In Lincolnshire, in at least one instance, the synchronal boundary, as indicated by the limits of a palæontological zone, is shown not to pursue the same stratigraphical horizon throughout its course, proving that sediments of different character were accumulated simultaneously in comparative proximity to each other. The inherent divergence between the stratigraphical and palæontological methods in geology is thus once more illustrated.
6. The derivative character of the band of phosphatic nodules at the base of the Spilsby Sandstone is stated to be very doubtful; and the fossils of these so-called 'pebbles,' as of the corresponding horizon at Speeton, are considered as probably representing an original fauna, poorly preserved in nodules formed during a temporary pause in the sedimentation.
7. It is shown that the 'Zone of *Belemnites lateralis*' bridges over the space between undoubtedly Jurassic and undoubtedly Lower Cretaceous strata; but if the accepted classification of other areas is to be upheld, it appears to be necessary that the division between the systems should be placed high enough to include this zone, or at least the greater part of it, in the Jurassic, in spite of the local inconvenience of this arrangement.

Discussion.

The President said that it was hardly possible, when mapping in the field, to do more than follow those petrological changes in the character of beds over any given area which are patent to the observer. The point discussed by the Author is that the life-line does not follow the line of the same sedimentation, but life-forms may transgress, and do transgress, over sediments of different character when they happen to be accumulated at the same time. It is hoped, however, that the case propounded by the Author is exceptional, and that, as a rule, the sediments and the fossils follow one another on the same lines.

Prof. Judd congratulated the Society upon the valuable details now communicated by the Author, and on the important work on

the fossils which had been done by him and Prof. Pavlow. He thought that the admissions of the Author, however, pointed to the desirability of the use of ammonite-zones in preference to those based on belemnites. He also demurred to the excessive importance attached to minute points of palæontological evidence when seeming to be in conflict with the stratigraphical evidence.

Mr. STRAHAN was prepared to find the palæontological and stratigraphical grouping of these rocks slightly at variance. He had pointed out some years ago that the Spilsby Sandstone became finer in grain and was partly replaced by clay eastwards. Northwards, towards Speeton, the same change took place, and no doubt the Author was correct in attributing a portion of the clay at Hundleby to that subdivision—on palæontological grounds. At the same time, it was inexpedient to draw any other line on the map than that which had been taken. The separation of Jurassic from Neocomian in Lincolnshire was based on stratigraphical considerations. A glance at the map showed that the Neocomian group followed the Upper Cretaceous through much of its range across Lincolnshire and Yorkshire; and though the great overlap took place at the base of the Upper Cretaceous, yet there was also an unconformity at the base of the Neocomian. So far as the North-east of England was concerned, no other division between Jurassic and Neocomian than that adopted by the Geological Survey was possible; had a local name been used in preference to the imported term 'Neocomian,' much confusion would have been avoided.

He had always regarded the nodule-bed in the Spilsby Sandstone as a true conglomerate—a natural accompaniment of the unconformity referred to. The nodules are clustered in a thin band at the base of the rock; they differ in their mineralization from the indigenous fauna; the recognizable forms resemble Kimeridge Clay as much as they do Neocomian forms; the nodules show every degree of wear and tear, and are rounded as though by rolling, and not pitted as they would be by corrosion, nor have they attached to them any of the original shell, nor any adherent organisms. He did not argue that they had been derived from beds now underlying the Spilsby Sandstone, but from strata that had been washed away. The same arguments were applicable to the nodules in the Carstone, which could be readily distinguished into indigenous and derived.

He thought it a matter for congratulation that they had had laid before them another of the Author's valuable contributions on this interesting group of rocks, and trusted that Mr. Lamplugh would eventually extend his observations to the South Coast.

Mr. H. B. WOODWARD remarked that, while in Dorset there was a passage from Kimeridge Clay into Portland Beds, in Lincolnshire the Spilsby Sandstone near Spilsby rested on Upper Kimeridge Clay and north of Caistor it rested on Lower Kimeridge Clay, so that there was a break between the nodule-bed and underlying clays. He said that it should be borne in mind that a similar nodule-bed, also containing derived Portlandian fossils, occurred at the base of the Woburn Sands at Brickhill, there resting on the Oxford Clay.

Mr. R. S. Herries congratulated Mr. Lamplugh on his paper and said that from his knowledge of the Author's excellent work at Speeton he felt every confidence in the correctness of his interpretation of the Lincolnshire sections. He was especially interested in that part of the paper which dealt with the boundary between the Neocomian and Jurassic, as in this he saw the elements of a reconciliation between the diverse views of Prof. Judd and the Author. He wished to say how much assistance he had derived from Prof. Judd's paper while working on the Speeton section.

Mr. G. C. Crick desired to bear testimony to the value of the paper. So far as the beds in question were concerned, he agreed with the Author in using the belemnites to characterize the various zones. He mentioned that much of the confusion which had arisen with respect to the determination of some ammonites, such as *Ammonites biplex*, was due to the unsatisfactory conditions of the types, some of these having been obtained from the Drift.

Mr. W. H. Hudleston also spoke.

The Author was glad to learn that Prof. Judd was inclined in the main to accept his results. As for the belemnites, their peculiar value as zonal fossils in the area described was, not only that they were abundant, but that owing to the intervention of the southern forms of the *jaculum*-group between the *lateralis*- and the *brunsvicensis*-groups of the northern *explanati*, the boundaries were very definite and easy to trace. He was quite ready to grant to Mr. Strahan and Mr. Woodward that an unconformity might exist at the base of the Spilsby Sandstone, and even that true pebbles might exist at this horizon, though he had himself failed to find any. His contention was, however, that the phosphatized casts of fossils were not derivative as had been supposed, but represented a fauna proper to the horizon and to some extent distinct from that of the overlying portion of the Sandstone. The condition of the casts appeared to be similar to that of the nodules dredged up by the *Challenger* expedition. He allowed that such nodules might form pebbles upon the destruction of their original matrix, but held that this explanation should be adopted only when the evidence was convincing, and not in such cases as this, where (as he had tried to show) it was insufficient. He thanked the Society for the kindly reception accorded to his paper.

9. *On some* Podophthalmatous Crustacea *from the* Cretaceous Formation *of* Vancouver *and* Queen Charlotte Islands. By Henry Woodward, LL.D., F.R.S., F.G.S. (Read January 22nd, 1896.)

Some time since I received from my friend Mr. J. F. Whiteaves, F.G.S., Palæontologist to the Geological Survey of Canada, several interesting crustaceans from the Cretaceous coal-bearing formation of Vancouver and Queen Charlotte Islands, and, as they offer a close affinity with forms from our own Gault and Greensand, they are deserving of special notice.

The existence of Cretaceous strata in Canada has long been known, and the coal-fields of Nanaimo and Comox on Vancouver Island have been correlated with this formation as well as those of Queen Charlotte Island and Alberta, eastward of the Rocky Mountains.

Mr. F. B. Meek in 1857 gave a description of new organic remains from the Cretaceous of Vancouver Island, including *Baculites ovatus* ? Say ; *Ammonites* (*Scaphites*) *ramosus*, *A. Newberryanus*, *Dentalium nanaimoensis*, *Thracia* (?) *occidentalis*, *Thr.* (?) *subtruncata*, *Trigonia Evansana*, *Pholadomya subelongata*, *Ph.* (*Goniomya*) *borealis*, *Cardium scitulum*, *Arca vancouverensis*, *A.* (*Cucullæa*) *æquilateralis*, and *Nucula Traskana*. Dr. B. F. Shumard in 1858 added *Inoceramus vancouverensis*, *Pinna calamitoides*, and *Pyrula glabra* to the Nanaimo fauna.

In Prof. H. Y. Hind's 'Report on the Assiniboine and Saskatchewan Expedition' (1859) further lists of fossils are given, 13 in number, all referred to Cretaceous forms, namely :—

Anomia Flemingii.
Inoceramus canadensis.
Avicula linguæformis, E. & S.
—— *nebrascana*, E. & S.
Leda Evansi, Hall & Meek.
Rostellaria americana, E. & S.
Natica obliquata, Hall & Meek.
Leda Hindi, Meek.
Avellana concinna, H. & M.
Ammonites placenta, Dekay.
Scaphites nodosus, Owen, var.
—— *Conradi*, Morton.
Nautilus Dekayi, Morton.

In 1861 Dr. (now Sir) James Hector instituted a comparison between the strata east of the Rocky Mountains with those of Vancouver Island (Capt. Palliser's Exploring Expedition, 1857–60).[1] The list of Cretaceous fossils contributed by Mr. Etheridge from east of the Rocky Mountains comprised :—

Ostrea anomiæformis.
—— *lugubris*, Conrad.
—— *cortex*, Conrad.
—— *vellicata*, Conrad.
* *Inoceramus Crippsii*, Roemer & C.
Leda Hindi, Meek.
Astarte texana, Conrad.
Cardium multistriatum, Shumard.
Cytherea texana, Conrad.
Pholadomya occidentalis, Morton.
Baculites compressus, Say.

* *Inoceramus Crippsii* (Roemer) and *Baculites compressus* (Say) are stated to be common to the Cretaceous rocks of the plains and of Vancouver Island; while of the whole 18 species no less than 13 are identified with Texan or Mexican species.

[1] Quart. Journ. Geol. Soc. vol. xvii. (1861) pp. 388–445.

Those from Nanaimo, Comox, or Valdez Inlet are:—

Inoceramus texanus, Conrad.
—— *nebrascensis*, Owen.
—— *undulatoplicatus*, Roemer.
—— *confertim annulatus*, Roemer.
Inoceramus mytiloides, Conrad.
Trigonia Emoryi, Conrad.
Cytherea leonensis, Conrad.
Ammonites geniculatus, Conrad.

In 1861 Mr. Meek (Proc. Acad. Nat. Sci. Philad. vol. xiii. p. 314) added to the list of Cretaceous fossils from Vancouver *Dosinia tenuis*, from Nanaimo; *Inoceramus subundatus*, *Baculites occidentalis*, *Ammonites vancouverensis*, and *Nautilus Campbelli*, from Comox; *Ammonites complexus*, var. *suciensis*, from Comox and the Sucia Islands; and *Baculites inornatus*, from the Sucia Islands.

In 1864 Mr. W. Gabb, in vol. i. of the 'Palæontology of California,' described and figured two new species of fossil shells, namely:—*Hamites vancouverensis* and *Pecten Traskii* from Nanaimo.

For an admirable summary of our knowledge of 'the Cretaceous System of Canada,' see the Presidential Address to the Royal Society of Canada by J. F. Whiteaves, Section iv., May 23rd, 1893, pp. 3–19 (Trans. Roy. Soc. Canada).

I find that it is impossible here to give a full list of all the fossils obtained from these beds, and I have omitted the fossils of the upper series of deposits entirely, as also the plant-remains.

Besides the mollusca, a decapod crustacean (named but not described as *Hoploparia* or *Podocrastes*? *dulmenensis*) has been recorded from the Niobrara-Benton group of Manitoba—a long-tailed decapod (*Palæastacus*) from the Pierre Fox Hills or Montana formation, and a beetle, *Hylobites cretaceus*, Scudder, from the Pierre Shales, Millwood, Manitoba.

The species of crustacea now to be noticed comprise:—

1. Several examples of a small macrurous decapod belonging to the genus *Callianassa*, met with very frequently in the Faxoe Beds, the Maestricht Chalk, the Greensand of Colin Glen, Belfast;[1] and also from lower beds (*C. isochela*),[2] Kimeridge Clay of the Sub-wealden boring; and from higher and later ones, namely, *Callianassa Batei*,[3] Upper Marine Series, Hempstead, Isle of Wight.

This is a small burrowing crustacean, and is found living at the present day; usually only the chelæ are obtained in dredging, owing to the animal lying in its burrow, and the hands alone protruding from the aperture.

The body- (thoracio-abdominal) segments are nearly soft, owing to the animal's constant habit of lying concealed, only the hands having a hardened calcareous covering.

[1] *neocomiensis*. H. Woodw. Brit. Assoc. Rep. (Norwich) 1868, p. 75, pl. ii. fig. 5.
[2] *C. isochela*, H. Woodw. Quart. Journ. Geol. Soc. vol. xxxii. (1876) p. 47, pl. xxxii. figs. 1, 2.
[3] *C. Batei*, H. Woodw. Brit. Assoc. Rep. (Norwich) 1868, p. 74, pl. ii. fig. 4.

I. MACRURA.

Tribe Thalassinidea.

Family Callianassidæ.

Genus Callianassa, Leach, 1814.

1. *Callianassa Whiteavesii*, sp. nov. (Figs. 1 & 2.)

General integument of body extremely thin, or semimembranous, except the first pair of feet, which are protected by a hard covering.

Anterior feet (chelipeds) very unequal: length of larger limb 39 millim.; breadth 9 millim.; the dactylus is straight, and is 9 millim. long, but the fixed thumb of the propodos is rudimentary and stout, being only half as long as the movable finger. Length of smaller hand about 20 millim. Surface of hands faintly wrinkled.

There are indications of the segments of the abdomen and of the thin integument with which they were covered, also of the small thoracic legs, but they are too much broken up for detailed description.

In this species from Vancouver Island the fixed thumb of the propodos is shorter than in any of the species hitherto recorded, and the movable finger (dactylus) is straighter.

The species is smaller than that from the Chalk of Dulmen, Westphalia, or from Maestricht, or Belfast. I have designated it *Callianassa Whiteavesii*, in honour of my friend Mr. J. F. Whiteaves, who has done so much for the elucidation of the Cretaceous formation in Canada.

Fig. 1.

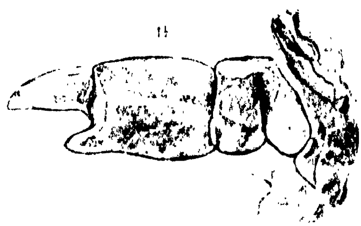


Fig 2.

Original specimens preserved in concretionary nodules of Cretaceous age from Comox River, Vancouver Island. Collected by Dr. C. F. Newcombe (1892). Museum of the Geological Survey of Canada, Ottawa.

A nodule from Vancouver Island, in the Geological Society's Museum, contains the remains of the large hands of *Callianassa Whiteavesii*. A second nodule from the same collection contains the carapace of *Plagiolophus vancouverensis*.

II. BRACHYURA—ANOMALA.

Family Homolidæ.

Genus Homolopsis, Bell.

Carapace longer than broad, quadrilateral; regions of carapace very distinct; branchial region large, triangular; orbits close together, frontal region rather produced; front subrotund.

2. *Homolopsis Richardsoni*, sp. nov. (Fig. 3.)

This interesting little crab was obtained by Mr. James Richardson in 1872 from Skidegate Inlet, west of Alliford Bay, Queen Charlotte Island, and is preserved in a hard black limestone-nodule containing plant-remains. Portions of the limbs still remain in their normal position, showing that it was entire when originally buried in the matrix.

Length of carapace 20 millim., greatest breadth 17 millim.; breadth of posterior border 14 millim.; breadth across hepatic region 14 millim.

The carapace is broadly quadrilateral, but pointed in front; the branchial regions extend to fully one half the length of the carapace; they are roughly triangular in shape, and nearly meet on the middle line behind the cardiac region; cardiac region small, shield-shaped, but elevated; metagastric region marked by two small prominences; hepatic regions prominent. Two very distinct and almost parallel furrows, the branchial furrow and cervical or hepatic furrow, diverge from the sides of the cardiac and metagastric regions obliquely forward towards the lateral margins of the carapace. Two deep submedian furrows mark the frontal portion of the cephalothorax, reaching to the rostrum, where they converge on the central line. Two small spines (or other appendages) project (as in the genus *Latreillia*) from the rostrum on either side.

Fig. 3.

The hinder border is extremely wide and straight, and suggests the broad margin for the attachment of the tail as in the females of all the Anomala, in which section the abdomen is only partially concealed beneath the cephalothorax.

The surface of the carapace, which is tumid, is coarsely and irregularly covered with small rounded tubercles, which are larger on the gastric and hepatic regions.

The walking-legs were evidently long and fairly large, and the chelipeds curved and tuberculated as in *Homola*.

This species has many points of resemblance to Reuss's *Prosopon verrucosum*, from which, however, it differs in the greater anterior breadth of Reuss's specimen, and in the form of the rostrum and arrangement of the furrows upon the gastric and cardiac regions. Reuss's *P. verrucosum* should probably be placed in Bell's genus

In *Homolopsis Edwardsii*, Bell, from the Gault of Folkestone, the frontal border is broader and the carapace more quadrate than in the North American form, which is pointed in front; the anterior half of the carapace in *H. Edwardsii* is more coarsely ornamented with fewer and larger tubercles, and the arrangement of the lobes differs considerably from that in *H. Richardsoni*.

I would refer this specimen to *Homolopsis*, and dedicate the species to the discoverer, Mr. James Richardson.

The specimen is from the Museum of the Geological Survey of Canada, Ottawa.

Legion OXYSTOMATA.

Family Corystidæ.

Genus PALÆOCORYSTES, Bell.

In this genus the carapace is longer than broad, flattish, becoming narrower gradually towards the posterior border, rostrum short, latero-anterior border dentated. Orbits moderately broad, with two fissures.

The carapace in all the species of this genus at present known is similar to that of the masked crab, *Corystes*, now living on our English coasts.

3. *Palæocorystes Harveyi*, sp. nov. (Fig. 4, p. 226.)

The genus *Palæocorystes*, to which I have referred two of the specimens sent to me by Mr. Whiteaves, is well represented in the Gault, Greensand, Chalk, and Eocene.

Thus we have:—

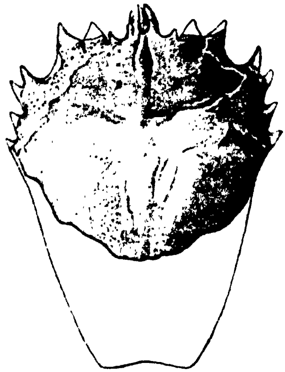
Palæocorystes Broderipii, Mantell, sp.; Gault, Folkestone.
—— *Stokesii*, Mantell, sp.: Gault and Greensand, Cambridge and Folkestone.
—— *Normanni*, Bell; Chalk Marl, Isle of Wight.
—— *Mulleri*, Bink; Upper Chalk, Maestricht.
—— *Callianassarum*, Fritsch; Chalk, Bohemia.
—— *ivericus*, Fritsch; Chalk, Bohemia.
—— *glabra*, H. W.; Lower Eocene, Portsmouth.
Eucorystes Carteri, M'Coy; Greensand, Cambridge.

Both the specimens from Canada are imperfect. One of them (No. 2) shows the anterior upper surface of the carapace, the other (No. 3) the posterior upper surface. From these we are able to make the following diagnosis:—

Specific characters. Length of carapace 35 millim., from the rostrum to the broken posterior border (to this we must probably

add 15 millim. more, making the total length from the rostrum to the posterior border of the carapace 50 millim.); greatest breadth across the hepatic region 37 millim.

Fig. 4.



(No. 2 was collected by Mr. W. Harvey, Comox River, Vancouver Island, 1892; No. 3 by Dr. C. F. Newcombe.)

Carapace smooth and gently convex in front, and very finely and minutely granulated. Latero-anterior border armed with four serrations on each side, frontal border marked by one prominent and one smaller tooth on either side of the small bifid rostrum, while two fissures mark the margin of each orbit. Under surface of carapace not exposed.

The regions of the carapace are very indistinct; two slightly divergent raised lines about 5 millim. in length mark the frontal region just behind the rostrum, and there is a faint ridge down the centre of the carapace. A small tubercle on either side, behind the frontal region, marks the epigastric lobe. A faint curved and bifurcating line separates the gastric from the cardiac regions, while two slightly rugose and incised lines curve outward and forward from the central cardiac region, marking the limits of the branchial region on either side.

Of the several species of *Palæocorystes* known, the present form, which I have ventured to call *P. Harveyi* after its discoverer, approaches most nearly to *P. Broderipii* from the Gault of Folkestone, but is probably one-third larger. The latero-anterior border of the former (*P. Harveyi*) has four spines on each side, whilst *P. Broderipii* has only two. The orbital regions differ in form, as well as the markings on the regions of the carapace.

We must await more complete materials before attempting a fuller and more careful description; meantime it is interesting to meet with a species from so distant a locality which apppoaches so nearly to our own Gault species *P. Broderipii*.

Formation.—Cretaceous. *Localities.*—Hornby Island (No. 2); and Comox River, Vancouver Island (No. 3).

No. 2 belongs to the Provincial Museum, Victoria, Vancouver Island; No. 3 belongs to the Geological Survey of Canada.

Legion Cyclometopa.

Family Cancridæ.

Genus Plagiolophus, Bell.

In this genus the carapace is transversely ovate, the regions of the cephalothorax are distinctly marked, front somewhat prominent,

the eyes subdistant, superior border of the orbits with two fissures, etc.

4. *Plagiolophus vancouverensis*, sp. nov. (Figs. 5 & 6.)

This crab is represented by four specimens, three of which I received from Mr. Whiteaves, and the remaining one is preserved in the Museum of the Geological Society.

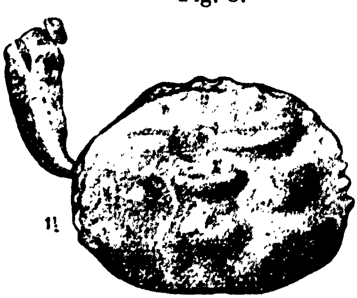
The carapaces vary in size from :—

	Millimetres long.	Millimetres broad.
1. Geological Society's specimen	22	28
2. From Comox River, Vancouver Island (fig. 5)	20	25
3. N.W. side, Hornby Island	16	20
4. N.W. side, Hornby Island (fig. 6) ..	10	13

No. 1 and No. 2 are ¼ broader than long, No. 3 is ⅕, and No. 4 is ⅓ broader than long.

The frontal border is straight; the rostrum is bifid, with two small rounded elevations divided by a groove; the orbital region is smooth and but little indented; the lateral borders are very gently rounded, the posterior border is nearly straight. The cardiac and metabranchial lobes, the metagastric and epibranchial lobes, and the two mesogastric lobes form three almost parallel lines across the carapace, giving it a very unique linear arrangement; there are also two much smaller lobes, one behind each of the orbits, flanked laterally by a small tubercle, and a small rounded tubercle on each epibranchial lobe; the lateral border was bluntly dentated.

Fig. 5.



1½

Fig. 6.

1½

When not waterworn (as in specimen No. 4), the surface of the carapace is in parts very finely granulated.

These specimens are very distinct, but without more materials I should not feel justified in separating them generically. I prefer rather to place them in Bell's genus *Plagiolophus*, which was proposed to receive *P. Wetherelli*, from the London Clay of Sheppey,

The same species—described under the name of *Glyphithyreus affinis* (Reuss)—was figured and described by Reuss nearly at the same date. Reuss also adds another species, *Glyphithyreus formosus*, Reuss, from the Upper Cretaceous of Mecklenburg.

I feel satisfied to leave these Vancouver Island crabs in this genus, and to designate them by the trivial name of *vancouverensis*.

Two specimens were collected on the north-western side of Hornby Island, and one on Comox River, Vancouver Island, British Columbia. The locality of the Geological Society's specimen is not marked, but it is from Vancouver Island.

Nos. 3 and 4, from Hornby Island, belong to the Provincial Museum of Victoria, Vancouver Island.

No. 2 specimen shows traces of limbs, and the flattened propodos of a chelate fore-arm 13 millim. long × 8 millim. broad.

10. *On a* Fossil Octopus (Calaïs Newboldi, J. De C. Sby. MS.) *from the* Cretaceous *of the* Lebanon. By Henry Woodward, LL.D., F.R.S., F.G.S. (Read January 22nd, 1896.)

[Plate VI.]

I am indebted to Mr. C. Davies Sherborn, F.G.S., for drawing my attention to a very remarkable and beautiful fossil from the Cretaceous formation of the Lebanon, Syria, obtained about 1846 by Lieut. T. J. Newbold, and presented by him to the Museum of the Geological Society, where it has since remained. In 1846 it attracted the attention of Mr. J. De Carle Sowerby, who evidently intended to describe it, 'at a more convenient season,' which never arrived; for he wrote upon it:—

'*Calais Newbouldii*' (read *Newboldi*). 'Ceph. Octopoda. *Genus ineditum. Abdomen alis triangularibus instructum.*

'*E strato calcareo tertiario Montis Libani a D.* (T. J.) *Newbo(u)ld effossum* 1846. J. De C. Sowerby.'

The only criticisms that I would venture to make upon this label are (1) that the stratum of limestone from the Lebanon, whence the fossil was derived, is not of 'Tertiary' but Cretaceous age; (2) that the specimen is marked in pencil on the back 'Major Newbold, Mt. Lebanon' (whose initials were 'T. J.'='Thomas John') not *D.*, and there should be no *u* in Newbold. He is spoken of in 1842 as 'Lieut. Newbold' (Proc. Geol. Soc. 1842, pp. 782–792), and by Murchison in his Presidential Address, Feb. 17th, 1843, as 'Lieut. Newbold, of the East India Company's service' (Proc. Geol. Soc. vol. iv. 1846, p. 137).

[In the 'National Biography,' 1894, pp. 314–315, Newbold is spoken of as one of the most accomplished officers in the East India Company's service. He was made a Lieutenant in 1834, and, while serving in Malacca, was Aide-de-camp to Brigadier-General E. W. Wilson, C.B. In 1840 he obtained leave and visited Egypt, Sinai, and Palestine, when he no doubt secured the fossil now under consideration. He was made a Captain, April 12th, 1842; but his later rank of Major is not mentioned by his biographer. He died at Mahabuleshwar on May 29th, 1850, at the age of 43 years. He wrote several important works on Indian Geology, on Egypt, the Sinaitic Peninsula, and Palestine, and he contributed 46 papers to various learned Societies.]

Prof. Lewis says, 'There are two principal localities for Cretaceous fossils known and recorded in the Lebanon, namely, Hâkel and Sahel-el-Alma, and a third of minor importance, called Hazhûla (Djoula on the French military chart), about 2 hours and a half south of Hâkel.

'Hâkel is the oldest known locality, though it has been but rarely visited. It is a long day's journey from Beirût, and is situated at about 800 to 1000 feet of elevation above the sea, and distant from the sea in a straight line about 6 miles.

'Sahel-el-Alma is nearer to Beirût, and may be visited from the

latter place in one day, with an allowance of two or three hours at the locality.

'The rock at Hâkel is somewhat harder than from Sahel-el-Alma, very fissile, and can be readily trimmed with the hammer.

'The section at Sahel-el-Alma is under the very walls of the old Convent, which gives its name to the spot; here, in a fig-orchard, outcrops the stratum of white chalky limestone where so many beautiful fossils have been obtained, and whence comes also the *Calaïs Newboldii*.'

The following is a brief summary of the bibliography of this classical locality:—

The existence of fossil fishes in the Lebanon is referred to in Joinville's 'Histoire de St. Louis'—edited by M. Natalis de Wailly. During the sojourn of the king at Sidon in 1253, just before his return home from the Crusades, a stone was brought him, says Joinville, 'which was the most marvellous in the world, for when a layer of it was lifted, there was found between the two pieces the form of a fish. The fish was of stone, but lacked nothing in form, eyes, bones, colour, or anything necessary to a living fish. The king demanded a stone and found a tench within.'

M. de Blainville described *Clupea brevissima* and *Clupea Beaurardi*, from Hâkel, in the Lebanon, in 1818.

Mr. Chas. Koenig, 1820, in his 'Icones Fossilium sectiles,' figured *Ophiura libanotica* and *Euryale Bajeri*, pl. ii. figs. 26 and 27, from the Cretaceous of the Lebanon.

Prof. L. Agassiz, in 1833–43 ('Poissons fossiles'), described two species of *Clupea* from Hâkel, and a *Sphyræna* and *Rhinellus* from Sahel-el-Alma.

Sir Philip Egerton added an account of *Cyclobatis* from Hâkel (Quart. Journ. Geol. Soc. vol. i. p. 225) in 1845.

Prof. Haeckel described two species of *Pycnosterinx* from Sahel-el-Alma, and a new species of *Clupea* from Hâkel, in 1849.

Mr. O. G. Costa described *Imogaster*, *Omosoma*, and *Beryx* in 1855.

In 1866 MM. Pictet and Humbert ('Nouvelles Recherches sur les Poissons fossiles du Mont Liban') described 26 species of fishes from Sahel-el-Alma and 21 from Hâkel.

(*Leptosomus macrurus*, described by Pictet and Humbert, Upper Cretaceous, Sahel-el-Alma, Mount Lebanon, is one of the fishes associated on the same slab with *Calaïs Newboldi*, the subject of this paper.)

Dr. Louis Lartet, in his fine memoir, 'Exploration géologique de la Mer Morte, de la Palestine et de l'Idumée' (1877), recorded, at p. 112, CLASS CEPHALOPODA. 1. OCTOPODA, '*Calaïs Newboldtii*,[1] Sow. Empreinte de Céphalopode dans les Calcaires à Poissons du Liban (Collection de la Société géologique de Londres).'

Lartet also mentions the remains of cephalopods of the family Sepiadæ from the same Cretaceous Limestone of the Lebanon (preserved in the Paris Museum).

[1] (The *t* in the specific name should be omitted.) 'Cette empreinte curieuse, très-bien conservée, a été recueillie par M. Newboldt.'

Prof. Dr. Oscar Fraas, in his work, 'Aus dem Orient,' 1878, pt. ii. (Stuttgart), figures and describes 28 species of invertebrata, echinodermata, mollusca, crustacea, etc., and 1 fish (*Gyrodus*) from the Cretaceous of Syria. He figures one dibranchiate cephalopod (*Geoteuthis libanoticus*) and 1 ammonite.

Dr. Fraas mentions that he saw in the collection of the Rev. Prof. E. R. Lewis, at the Syrian Protestant College, Beirût, a specimen of *Sepialites* with eight arms, of which he secured a photograph; and that Sowerby had long ago obtained from the Lebanon an *Octopus* collected by Mr. Newbold, to which he had given the name of *Calais Newboldi* ('Aus dem Orient,' ii. p. 90).

In the same year (1878) the Rev. Prof. Lewis, F.G.S., gave an interesting description of the Fossil Fish Localities of the Lebanon in the Geological Magazine (pp. 214–220).

In 1879 I described before this Society *Squilla Lewisii* and *Limulus syriacus* from the Lebanon Cretaceous (see Quart. Journ. Geol. Soc. vol. xxxv. pp. 552–556, pl. xxvi.).

In 1883 I described a new genus of fossil 'Calamary,' *Dorateuthis syriacus*, from the Cretaceous of Sahel-el-Alma (see Geol. Mag. 1883, pp. 1–5, pl. i.).

In 1882 Mr. W. H. Hudleston, F.R.S., gave in his Presidential Address to the Geologists' Association an admirable account of the 'Geology of Palestine,' in which the geological horizon of the Hâkel and Sahel-el-Alma deposits is discussed, with a coloured map and a plate (Proc. Geologists' Association, vol. viii. 1883–84, pp. 1–53) (see also 'Further Notes,' Proc. Geol. Assoc. vol. ix. 1885, pp. 77–104).

In 1886 Prof. Dr. W. Dames published an account of ten genera and twelve species of crustacea from the Cretaceous of the Lebanon. Among them is one figured and described as *Protozoëa Hilgendorfi*, Dames, which is represented by three specimens on the slab which contains *Calais Newboldi* (Zeitschr. d. deutsch. geol. Gesellsch. vol. xxxviii. 1886, p. 577, pl. xv. figs. 5–7).

The fossil remains of *Calaïs Newboldi* are preserved as a delicate ferruginous impression upon the biscuit-coloured surface of one of the fissile slabs of Cretaceous Limestone from Sahel-el-Alma, Mount Lebanon.

The slab is $9\frac{1}{2}$ inches long by 8 in breadth and 1 in thickness, displaying remains of fossil organisms upon both its surfaces.

These consist of several small well-preserved fishes, *Leptosomus macrurus*, Pictet & Humbert, and a small crustacean carapace (believed to be a zoea-form) and named *Protozoëa Hilgendorfi* by Dames.

The *Octopus*, which occupies the centre of the slab, exhibits its eight arms (or more properly feet or 'podites'), each furnished with a row of suckers, which diminish in size gradually from their base to the very slender extremities of the podites. Near the union of the podites with the head, there is a faint trace of what

may have represented the umbrella, or 'web,' which once united the arms or podites together.

In the centre of the head (between the bases of the arms or podites) is a darker and denser spot of brown showing evidence of the beaks,—marking the position of the mouth; below this again is a small slightly-raised orifice, which probably marks the opening of the funnel. Two remains of fishes lie across the neck and separate the head and arms above from the round wrinkled body beneath, with its triangular fins, a feature which at once distinctly characterizes this genus.

An injudicious attempt to develop the two mutilated fishes, lying across the Octopod, has resulted in the unfortunate removal of a part of the thin and delicate layer on which the Nature-painting of *Calaïs* was preserved. In the centre of the body is an oval depression or cavity 8 mm. long and 4 mm. broad, once occupied by the ink-bag. The breadth of the body is 40 mm., and to the extremity of the lateral fins 64 mm.; height of fin 14 mm. Length of arms rather over 100 mm. Breadth of arm near the head about 5 mm., but diminishing rapidly to 4 and 3 mm., and terminating in a slender whip-like extremity.

There appears to be only a single row of suckers upon each arm, as in the genus *Eledone*, and about 30 suckers in each row. The suckers vary in size from 2 mm. in diameter to less than 1 mm. Some of the suckers seen in profile stand up as much as 2 mm. from the surface of the arm.

There is a faint trace of the presence of an umbrella, or web, uniting the bases of the arms around the mouth to a distance of about 15 mm. The arms were evidently very flexible, judging by the graceful curves which they have assumed even in death. They are also seen to be of nearly equal size and length, so far as can be ascertained.

As I have already stated, the triangular 'alæ,' or more properly 'fins,' are characteristic of *Calaïs*. S. P. Woodward ('Manual of the Mollusca,' p. 64) says of the Octopods, 'their bodies are round, and they seldom have fins.'

In *Pinnoctopus* the body has lateral fins united behind (ex. *P. cordiformis*). In *Cirroteuthis* the body has two transverse fins. In *Calaïs*, as we have seen, the body is round, but it is provided with triangular lateral fins (not united behind).

In the decapoda—cephalopods with eight arms and two tentacles, or, as they are often called, 'tentacular arms'—the body is oblong or elongated, and is always provided with a pair of lateral or nearly terminal fins.

Sepiola has rounded dorsal fins, but in very many genera the fins are terminal and often rhombic or angular.

The question of the position of the arms, whether uniform in size and freely-moving, or differing in size and position in relation to the dorsal and ventral aspect of the body, is of some importance even in studying these fossil remains.

Thus, for example, in his work, 'Aus dem Orient,' vol. ii. p. 90,

Dr. Fraas refers to a specimen which he had seen at Beirût in the collection of the Rev. Prof. Lewis; this showed the head of a sepialite with its eight arms close together, and, as he says, reminded him of the fossil forms from the Lias, figured and described by Quenstedt.

Dr. Fraas obtained a photograph of this 'sepialite' from Prof. Lewis, which was afterwards lent to Mr. G. C. Crick, F.G.S., who compared it with specimens obtained by the British Museum from the late Prof. Lewis, and was happily able to identify by its aid the original of Dr. Fraas's remarks.[1]

The specimen proves to be the head and arms of a decapod cephalopod allied probably to *Onychoteuthis*, showing the eight ordinary arms, but with only a faint trace preserved of one of the long tentacular arms.

The arms are close together and nearly straight, and are arranged in pairs. First there is a pair of slender and short dorsal arms, then two pairs of very stout and longer lateral arms, and, lastly, another pair of somewhat shorter and more slender ventral arms.

Plesioteuthis Fraasii, *sp. nov., from the Cretaceous of the Lebanon.*

No suckers are visible on the arms, but there are traces of what appear to be hooklets and serrations in two or three places, so that, taken in connexion with the more rigid carriage of the arms and their arrangement in pairs, we may feel assured that this is not an octopod, like *Calaïs*, but a true Teuthid[2] and probably related to *Dorateuthis* (see Geol. Mag. 1883, pl. i. p. 1).

[1] The photograph was marked in pencil *Calaïs Newboldi.*

[2] If a name be desired, I would suggest for this sepialite the name of *Plesioteuthis Fraasii*, after the author of 'Aus dem Orient.'

Length of the largest arms 7 inches, of the shortest pair of dorsal arms 4 inches; the second or ventral pair of slender arms are 5 inches long. The head with the arms is nearly 10 inches in length. The beak is $\frac{3}{4}$ inch in length and $\frac{4}{12}$ inch broad at its base.

At present, so far as my information serves, *Calaïs Newboldi* remains the oldest and only known fossil octopod.

I have retained Mr. J. de Carle Sowerby's original name, it having been already recorded in print by Dr. Oscar Fraas and by Dr. Louis Lartet in their respective works already referred to.

The genus *Călăïs* is derived from Călăïs, the brother of Zetes (sons of Boreas and Orithyia), frequently called the Borĕădæ (mentioned among the Argonauts), and described as winged beings. [Smith's Classical Dictionary, 1883.]

Postscript.

The genus *Dorateuthis*, proposed by myself in 1883, is by Zittel included in the genus *Plesioteuthis* of A. Wagner (1860), which has also a tricarinate internal pen with a spatulate distal expansion.

There are now in the British Museum (Natural History) as many as ten Teuthidæ,[1] the largest of which is 20 inches in length, and exhibits the body, head, and arms in union. The smallest is not so large as *D. syriacus*, H. W. (1883). They all possess tricarinate shells.

I hope to offer some further notes upon these very well-preserved decapod cephalopoda from the Lebanon later on, with the promised kind co-operation of Mr. G. C. Crick, F.G.S., who has devoted so much attention to the cephalopoda generally, and to whom I am indebted for information and assistance in preparing this paper.

PLATE VI.

Calaïs Newboldi from the Cretaceous of the Lebanon.

Discussion.

Mr. Crick stated that, as the occurrence of this fossil had been already at least twice recorded, and as neither a description nor a figure had been given hitherto, it was most important that the specimen should be described and figured, and it was very fortunate that the fossil had come into the hands of the President for description. He believed the specimen to be a true octopod; it was therefore the oldest known representative of this division of the cephalopoda.

[1] All from Prof. Lewis's collection of Lebanon Cretaceous fossils.

11. *The* British Silurian Species *of* Acidaspis. By Philip Lake, Esq., M.A., F.G.S. (Read December 18th, 1895.)

[Plates VII. & VIII.]

Contents.

I. Introduction.

The genus *Acidaspis* has been a peculiarly unfortunate one in Britain. Several of the specific names which are in common use are manuscript terms, or but little better; and the species to which they are applied have never been described. It is impossible, therefore, without access to standard collections, to determine to what forms the names refer. Even the species which have been described have in many cases been imperfectly figured, and the result is endless confusion. The common English trilobite, *A. coronata*, has received abroad no less than three names, all of them different from ours; while in England, on the other hand, the foreign name *A. crenata* is often applied to a species which is quite distinct from the original *A. crenata*, and which in fact has never yet been found out of Britain.

The disorder is worst among the Silurian forms, although these are much the most perfect. The Ordovician species are usually fragmentary, but the fragments have been fully described.

It is the object of the present paper to attempt to reduce the specific terminology to some sort of order, and to rescue the common manuscript names from the obscurity in which such terms tend to become involved after a lapse of time. Only the Silurian forms are here described; the Ordovician species have been left in the hope that better material may be forthcoming in the future.

Even the name of the genus itself is matter of controversy. Murchison [1] employed the term *Acidaspis* in 1839, and in the same year Emmrich [2] proposed the name *Odontopleura*. The latter is often used in Germany, but the former is the more widely spread. There is, however, an earlier name still, the use of which has been advocated by Vogdes [3] and J. M. Clarke,[4] though Vogdes, in his bibliography,[5] does not adopt his own suggestion. This name is *Ceratocephala*, and was applied by Warder [6] in 1838 to a species which he called

[1] 'Silurian System,' p. 658.
[2] 'De Tril. Diss. inaug.' 1839, Berlin.
[3] Proc. Acad. Nat. Sci. Philadelphia, 1877, p. 138.
[4] 44th Ann. Rep. New York State Museum (1891), p. 91.
[5] Bibl. Pal. Crust. 1893, San Francisco.
[6] Amer. Journ. Sci. & Art, vol. xxxiv. no. 2 (1838), p. 377.

Ceratocephala goniata, and which belongs to the same group as *A. vesiculosa* etc. Warder's name was rejected by Corda on the ground that it had already been employed, in the form *Ceratocephalus*, for a genus of plants; but even if it be eligible, its rival, *Acidaspis*, has been so widely used for so long a time that, here at least, I do not propose to adopt any other.

II. Description of Species.

Acidaspis Brighti, Murch. (Pl. VII. fig. 5.)

1839. *Acidaspis Brightii*, Murch. 'Sil. Syst.' p. 658, pl. xiv. fig. 15; 1848. Salter, Mem. Geol. Surv. vol. ii. pt. i. p. 348, pl. ix. figs. 6(?), 7 (not figs. 8, 9).
(Not *Odontopleura Brightii*, Beyrich, 'Unters. über Tril.' p. 20, pl. iii. fig. 6.)

Head transverse, crescentic, with one occipital and two genal prolongations or arms; tuberculate. Glabella prominent; central portion nearly uniform in width throughout, but slightly contracted between the second pair of lateral lobes; lateral lobes two on each side, almost completely separated from the central portion; the basal lobe much the larger of the two. Occipital ring very indistinctly separated from the glabella, produced backward into a single, strong, straight median spine. Eyes placed far back, and very near to the basal lobe of the glabella; connected with the front end of the glabella by a nearly straight ocular ridge. Free cheeks small, with a raised margin, which bears a number of spines directed downward; genal angles produced into long and strong spines, which form a continuous curve with the posterior margin of the head, but make a distinct angle with the external margin.

Horizons and Localities.—Wenlock Limestone: Dudley. Lower Ludlow: near the Wych, Malvern. It has been recorded from the Bala beds, but this is probably due to mistaken identification.

Affinities.—Only the head is known with certainty. It closely resembles *A. Grayi*, Barr., but is distinguished, as Barrande has pointed out, by the following characters:—(1) the genal spines in *A. Brighti* are inclined to the axis at an angle of about 45°, while in *A. Grayi* they are nearly at right angles to it; (2) the occipital spine in *A. Brighti* is usually somewhat smaller than in *A. Grayi*, and does not bear the prominent tubercle characteristic of the latter; (3) the ocular ridge in *A. Brighti* is nearly straight, in *A. Grayi* strongly arched; (4) the granulation in *A. Brighti* is much coarser and stronger than in *A. Grayi*.

It is easily distinguished from all other British species by the single strong occipital spine.

Remarks on the Synonymy.—The species was originally described and figured by Murchison, and formed the type of his genus *Acidaspis*. In 1848 Salter gave a fuller account of the form; but unfortunately he confounded two species under the same name, and figured two distinct heads and two distinct tails. One of the species is identical with *Paradoxides quadrimucronatus*, Murch., and hence this name is usually quoted as a synonym of *A. Brighti*. Subsequently Salter recognized his error, and in 1857 he described the

second species under the name of *A. coronata*. This, and not *A. Brighti*, is the *Paradoxides quadrimucronatus* of Murchison.

Beyrich's *Odontopleura Brightii* is a different species, and is identical with *Acidaspis quinquespinosa*, Salter MS.

ACIDASPIS CORONATA, Salter. (Pl. VII. fig. 6.)

1839. ? *Paradoxides quadrimucronatus*, Murch. 'Sil. Syst.' p. 658, pl. xiv. fig. 10.
1845. ? *Odontopleura mutica*, Emmrich, Neues Jahrb. 1845, p. 44; 1846. Beyrich, 'Unters. üb. Tril.' p. 19, pl. iii. fig. 5.
1848. *Acidaspis Brightii* (pars), Salter, Mem. Geol. Surv. vol. ii. pt. i. p. 348, pl. ix. figs. 8, 9 (not figs. 6, 7).
1853. *Acidaspis coronatus*, Salter, Mem. Geol. Surv. dec. vii. pl. vi. p. 7; 1854. Morris, 'Catalogue of Brit. Fossils,' 2nd ed. p. 99.
1854. *Acidaspis Marklini*, Angelin, 'Pal. Scand.' p. 38, pl. xxii. fig. 13.
1854. *Acidaspis multicuspis*, Angelin, 'Pal. Scand.' p. 37, pl. xxii. fig. 12.
1857. *Acidaspis coronata*, Salter, Quart. Journ. Geol. Soc. vol. xiii. p. 210.
1885. *Acidaspis Marklini*, Lindström, Öfv. kongl. Vet.-Akad. Förh. Årg. 42, no. 6, p. 54, pl. xiii. figs. 8, 15, pl. xvi. fig. 10.
1888. *Acidaspis mutica*, Wigand, Zeitschr. deutsch. geol. Gesellsch. vol. xl. p. 93, pl. x. figs. 19, 20.

General form broadly ovate, depressed.

Head large, semilunar, the angles drawn out into broad spines; granulate. Glabella triangular; median portion nearly parallel-sided; the basal lateral lobe is considerably larger than the second; both are rounded and well-defined, but confluent on the inner side with the median portion of the glabella; anterior lateral lobes obsolete. Frontal border nearly straight, smooth, projecting beyond the margin of the free cheeks. The facial suture in front of the eye is nearly parallel to the axis, behind the eye is continued almost at right angles, and cuts the posterior margin not far from the genal angle. Eyes small, prominent, placed far back, close to the occipital furrow; ocular ridge curved. Free cheeks easily separable, granular, steeply inclined, bearing at the margin a row of about twelve short spines; produced at the genal angles into broad spines, the borders of which are nearly continuous in direction with the borders of the cheeks.

The thorax consists of ten segments. Axis narrow. Pleuræ straight, at right angles to the axis; produced into spines, which are strongly bent backwards. Each pleura bears a prominent ridge, on which is a row of small tubercles, sometimes indistinct. The spines also are granulate.

Tail broad, short. The axis consists of two segments. From the anterior ring a strong rib proceeds on each side to the margin, where it is produced and forms a primary spine. There are four secondary spines between the two primaries, and one outside each. All the spines are directed straight backward, and they are generally short. The margin, spines, and other prominent parts bear tubercles, and there is generally one somewhat larger than the average, at the base of each spine.

Horizons and Localities.—Wenlock Limestone: Dudley; Walsall; Malvern; Pen-y-llan, Cardiff. Lower Ludlow: Vinnal Hill, Ludlow; Dudley. A very much crushed specimen in the Museum of Practical

Geology, Jermyn Street, from the Upper Llandovery of Pen-y-llan, seems to belong to this species.

Affinities.—This species closely resembles *A. deflexa*, from which, however, it may be distinguished by the following characters:—(1) the external border of the genal spine in *A. coronata* forms a curve nearly continuous with the external margin of the cheek; in *A. deflexa* there is a distinct angle between the two; (2) the tail of *A. coronata* bears eight short points, all of which are parallel to the axis, while the tail of *A. deflexa* bears only four spines and a rudimentary point at each of the anterior angles.

Synonymy.—*A. coronata* has been one of the most unfortunate species of an unfortunate genus. At the present day it bears three distinct names, all of which are in common use. It is known as *A. coronata* in England, *A. Marklini* in Sweden, and *A. mutica* in Germany; and even yet it is not clear which of these names it ought to bear. Murchison's term *quadrimucronatus* is older than any of them; but it is so entirely misleading, and his description is so incorrect, that although his figure is just recognizable, the name can scarcely stand. Moreover, it is possible that all palæontologists may not consider Murchison's figure unmistakable.

The oldest of the other three names is *mutica*; but although our species is identical with *A. mutica* as figured and described by Wigand, it is by no means certain that it is the same as *Odontopleura mutica* of Emmrich and Beyrich. Emmrich's description is too brief to be of any value; but Beyrich's account of the species states that the thorax has only 9 segments, while in his figure the spines of the tail are radiate instead of parallel. Until, therefore, Emmrich's or Beyrich's type has been re-examined, it is impossible to apply the name to the English form.

In 1848 Salter figured and described *Acidaspis Brightii*, Murch., but unfortunately, along with a specimen of the true *A. Brighti*, he figured also a head and a tail of our present species. In 1853 he had discovered his mistake, and proposed the name *coronatus* for the new form, pointing out at the same time which of his figures belonged to it; but it was not till 1857 that he published a description.

In the meantime Angelin had described and figured the thorax and tail of the same trilobite as *A. Marklini*, a name which has not unnaturally been accepted in Sweden. Under the impression that it belonged to a distinct species, he gave to the head of this form the name of *A. multicuspis*. Angelin's figures are not good, but Lindström has since given an accurate description of the species with good figures; and from an examination of the original specimens in the Riksmuseum at Stockholm I am able to state that the Swedish and English species are identical.

Thus there is plenty of room for difference of opinion, and it is not without hesitation that I have adopted Salter's name. But, putting aside Murchison's term, Salter's was the first which was applied to a recognizable figure of the species.

ACIDASPIS DEFLEXA, sp. nov. (Pl. VII. fig. 7.)

This resembles *A. coronata* so much that a full description is unnecessary, and it will be sufficient to draw attention to the chief points of difference.

Head as in *A. coronata*; but the genal spines are more slender, and their outer borders make a distinct angle with the external margin of the cheek.

The thorax consists of ten segments, as in *A. coronata*; but the pleural spines are somewhat more delicate.

Tail rather large, broad. Axis small, with two rings defined upon it; from the anterior ring a rib curves back on each side, and is produced beyond the margin of the tail as a long slender spine, slightly inclined outwards. Between these two primary spines are two shorter ones, and outside each primary is a rudimentary point.

Horizon and Localities.—Wenlock Limestone: Dudley; Walsall.

Affinities.—This is one of the forms which are commonly called *A. crenata* in England; but it is quite a distinct species, and is much more closely allied to *A. coronata*. From *A. crenata* it is distinguished by the outline of the head, the strength of the genal spines, the absence of crenation on the frontal border, etc. From *A. coronata* it is separated by the characters of the genal spine and of the tail, as described above.

ACIDASPIS CRENATA, Emm. sp. (Pl. VII. figs. 1 & 2.)

1845. *Odontopleura crenata*, Emmrich, Neues Jahrb. 1845, p. 44.
1845. *Ceraurus crenatus*, Lovén, Öfv. kongl. Vet.-Akad. 1845, p. 47, pl. i. fig. 1.

Body oval, broad in front, narrowing rapidly behind.

Head sub-quadrate, about twice as broad as long, margin incurved in front. The glabella narrows slightly towards the front; basal and second lobes rounded, nearly equal in size, almost completely cut off from the central part of the glabella. The occipital ring bears a small tubercle. Frontal border crenate. Facial suture in front of the eye nearly parallel to the axis, behind the eye it cuts the posterior margin. Eyes very prominent, placed far back, close to the neck furrow and near to the glabella. Free cheeks granular; margin provided with short spines; genal angle produced into a long slender spine, which at its origin is curved outward.

The thorax consists of nine segments, which after the first two or three decrease in width towards the tail. Axis about as wide as the pleuræ. Pleuræ nearly at right angles to the axial line; each bears a prominent ridge, which, except in the case of the first two segments, is produced into a long, slender, backwardly-directed spine.

The tail exists in two forms (each of which has been found attached to a complete specimen):—(1) very small; consists of two segments, the anterior of which is produced backward into a long spine on each side; two very short spines between these primaries; (2) much broader, with a broad flat area around the axis; primary spines not so long, secondary spines larger. These two forms probably belong to different sexes.

Horizon and Locality.—Wenlock Beds: Dudley.

Affinities.—As already remarked, *A. deflexa* has usually been mistaken for *A. crenata*; but the resemblance is not very striking, and the differences have already been noted. *A. Barrandei*, Ang., is very close to *A. crenata*, and indeed is only distinguished by the presence of a pair of tubercles on each ring of the axis and on each pleura. Several of the British specimens show tubercles upon the axis and pleuræ. The presence or absence of these tubercles is probably not a character of specific value, and depends, in part at least, upon whether the actual test of the animal is preserved.

The specimens of *A. crenata* in the Riksmuseum at Stockholm show both forms of tail. Lovén's figure belongs to the narrow-tailed variety.

ACIDASPIS QUINQUESPINOSA, Salter MS. (Pl. VII. figs. 3 & 4.)

1846. *Odontopleura Brightii*, Beyrich, 'Unters. üb. Tril.' p. 20, pl. iii. fig. 6.
1854. *Acidaspis quinquespinosus*, Fletcher & Salter, in Morris's 'Catalogue of Brit. Fossils,' 2nd ed. p. 99; 1873. Salter 'Cat. Cambr. & Sil. Foss.' p. 134.

Body broadly ovate.

Head short, broad, nearly straight in front; surface tuberculate. Glabella triangular, occupying at the base about one-third the width of the head; three pairs of lateral lobes separated one from another by lateral furrows, but not cut off from the median part of the glabella. The facial suture, represented by a raised ridge, runs in a straight line from the anterior margin to the eye and thence in a sigmoid curve to the genal angle. Eyes small, set somewhat behind the middle of the cheeks; a straight ocular ridge runs from each to the anterior corner of the glabella. Fixed cheeks broad, the portion between the ocular ridge and the glabella tumid. Free cheeks with a raised margin, which bears a row of short spines; produced at the genal angle into a short curved spine. Axial part of occipital ring broad, and bearing on its posterior margin five small spines; the posterior margins of the cheeks each bear two spines, exclusive of that at the genal angle.

The thorax consists of ten segments, and is broader than it is long. Axis very broad, more than one-third the total width. Pleuræ horizontal till near the margin, when they are abruptly bent downward and then produced into short curved spines; the anterior pleuræ are at right angles to the axial line, the posterior pleuræ slightly inclined backward, and this is true, in a more marked degree, of the spines. Each pleura bears a prominent tuberculate ridge.

Tail short, broad, forming a segment of a circle; it bears one curved ridge on each side, which is produced to form a short primary spine. Outside each primary spine are two secondaries; and between the primaries are four secondaries. Margin of tail raised.

Horizon and Locality.—Wenlock Limestone: Dudley.

It is on the authority of specimens in the Woodwardian

Museum, referred to in Salter's 'Catalogue,' that the name is applied to the species here described.

ACIDASPIS BARRANDEI, Fletcher & Salter, *non* Angelin. (Pl. VIII. figs. 1–3.)

1848. *Acidaspis bispinosus*, Salter, Mem. Geol. Surv. vol. ii. pt. i. pl. ix. fig. 4 (only).

1853. *Acidaspis Barrandii*, Fletcher (*dixit* Salter), Mem. Geol. Surv. dec. vii. p. 6, pl. vi.; 1854. Fletcher & Salter, in Morris's 'Catalogue of Brit. Fossils,' 2nd ed. p. 98; 1859. Murchison, 'Siluria,' 3rd ed. p. 261, Foss. 64, fig. 9.

General form quadrate, nearly as wide behind as in front.

Head quadrate, widest in front, tuberculate. Axal furrows almost obsolete; median portion of glabella swollen, narrows slightly towards the front; two pairs of lateral furrows deeply impressed; lateral lobes very indistinctly separated from the cheeks. Facial suture invisible. Eye small, prominent, set in the middle of the cheeks; ocular ridge straight. Fixed cheeks large and tumid. The free cheeks widen out towards the front, with a broad tuberculate raised margin bearing a row of short spines. Moderately long slender spines at the genal angles, but these do not appear to spring from the margin. The axal part of the occipital ring is produced into a pair of spines directed backward and outward.

The thorax consists of ten segments. Axis wide; each segment bears two prominent tubercles. Pleuræ broad, flat, tuberculate; at a distance from the axis about equal to the width of the axis, all but the last are abruptly bent downward and produced into a short ornamented spine (very rarely visible); and from the angle of the bend long horizontal spines are given off. The horizontal spines are arranged in a radiate fashion, those from the anterior segments being directed slightly forward, and those from the posterior segments backward. The last segment differs from these, and bears two ornamented horizontal spines on each side.

Tail broad, tuberculate; axis ill-defined. The margin bears five longer spines, one being median, and from the front of the base of each lateral spine is given off a smaller ornamented spine, thus making a total of nine.

Horizon and Locality.—Wenlock Limestone: Dudley, Callow Farm.

Affinities.—*A. Barrandei* is closely allied to *A. Verneuili*, Barr., and *A. vesiculosa*, Beyr., and in fact is chiefly distinguished by the characters of its tail. *A. vesiculosa* has five spines to its tail, *A. Verneuili* seven, and *A. Barrandei* nine.

A. bicuspis, Ang., belongs to the same group. Only one specimen, which is now in the Riksmuseum at Stockholm, appears to have been found, and it is scarcely perfect enough to allow of one's asserting with confidence whether it is a distinct species or not.

Synonymy.—The head of this species was originally figured by Salter in 1848 under the name *A. bispinosus*. In 1853 he corrected his mistake, and stated that the form had been named *A. Barrandii* by Fletcher, and would shortly be described. Since then this name has been in common use in England; but no description seems

ever to have been published. Unfortunately, in 1854, Angelin adopted the name *A. Barrandei* for a species quite distinct from this, and allied to *A. crenata*. As, however, Fletcher's name had already been published and applied to a definite figure, it would appear to have priority.

Acidaspis Hughesi, Salter MS. (Pl. VIII. figs. 4 & 5.)

1873. *Acidaspis Hughesii*, Salter, 'Cat. Cambr. & Sil. Foss.' p. 93.

General form depressed, broadly ovate.

The head forms a transverse semi-oval. The glabella consists of a parallel-sided median portion and two lateral lobes on each side, completely cut off from the median portion; the basal lobe is much the larger. The facial suture cuts the posterior margin just within the genal spine. Eyes small, set somewhat far back. Fixed cheeks narrow, tumid. Free cheek broad, granulate, provided with a raised margin bearing a row of spines, which become longer towards the genal angle; genal angle produced into a short weak spine directed backward and outward. The axis of the neck-segment bears two short spines, which are seldom visible.

The thorax consists of nine segments, and is of nearly equal width throughout. Axis narrow, about one fourth the total width of the body. Pleuræ straight; the greater part of each is occupied by a broad prominent ridge, which bears a row of some half-dozen tubercles; on each side of this main ridge is a very narrow band, the anterior one being somewhat the broader, slightly raised and finely tuberculate. Both the central and the anterior ridges are produced into spines, those from the former being considerably the longer. These spines curve backward and increase in length towards the posterior end of the body.

Tail broad, granulate. The axis consists of two rings and a terminal knob, the second ring being often very indistinct. The margin bears a row of radiating spines, namely:—2 larger spines connected with the axis by a rib; 4 smaller ones between these; and 4, or perhaps 5, outside each of the larger spines.

Horizons and Localities.—In the Jermyn Street Museum there are specimens of this species from Brownthwaite, Gale Garth, Casterton Low Fell, and Ravenstone Dale. The last three localities are referred to the Upper Coldwell Beds by Mr. Marr,[1] who also records the species from the same beds at Helm Knot. In the Woodwardian Museum there are specimens collected by Prof. Hughes from beds above the Nant Glyn Flags at Pont Lawnt in Denbighshire, which he believes to be on the same horizon as the beds of Casterton Low Fell.[2]

The specimen on which Salter is stated to have founded the species was brought from Casterton Low Fell, and is now in the Woodwardian Museum.

In the Jermyn Street Museum there is a specimen of *Acidaspis* which is stated to come from the Llandeilo Flags near Pencerrig

[1] Geol. Mag. 1892, p. 538.

[2] Proc. Chester Soc. Nat. Sci. & Lit. pt. iv. 1893, p. 154.

House, Builth. So far as can be seen, and the specimen is nearly complete, it is indistinguishable from *A. Hughesi*; but it is difficult to believe that this species can occur so low down in the geological scale. Pencerrig lies close to the boundary between the Wenlock and Llandeilo Beds, and it is possible that the specimen may have been obtained from the former.

ACIDASPIS ERINACEUS, Marr & Nicholson.

1888. *Acidaspis erinaceus*, Marr & Nicholson, Quart. Journ. Geol. Soc. vol. xliv. p. 723, pl. xvi. figs. 11 & 12.

This species having been recently figured and described, the only point to which it is necessary to call attention here is that the original of Messrs. Marr and Nicholson's fig. 11 shows, somewhat indistinctly, the frontal border in front of the glabella. The free cheeks are lost in the specimens, and hence the form of the head, with the glabella apparently projecting in front, seems abnormal in the figure.

The species is compared by Marr and Nicholson with *A. centrina*, Dalm., from the same horizon in Sweden.

Horizon and Locality.—Llandovery Beds: in the *Acidaspis erinaceus*-zone of the Stockdale Shales at Torver Beck.

ACIDASPIS CALLIPAREOS, Wyv. Thomson.

1857. *Acidaspis callipareos*, Wyv. Thomson, Quart. Journ. Geol. Soc. vol. xiii. p. 208, pl. vi. figs. 11, 12; 1878. Nicholson & Etheridge, 'Mon. Sil. Foss. Girvan,' p. 125.

Only the head is described by Wyville Thomson; and it is believed by Nicholson and Etheridge to be probably the head of *A. hystrix*. The two, however, are stated to have been found on different horizons. Wyville Thomson considers *A. callipareos* to be very closely allied to *A. pectinata*, Ang.

Horizon and Locality.—According to Wyville Thomson, the specimens were found in the Mullock Hill Sandstone near Girvan. This is of Llandovery age.

Two other species, to which Fletcher and Salter[1] gave the names of *Acidaspis Dama* and *A. dumetosus*, are stated to occur in the 'Upper Silurian' at Dudley. No description of them has been published; and I have been unable to find, in the various collections arranged by Salter, any specimens ascribed to *A. dumetosus*. In the Jermyn Street Museum several fragments from various horizons are referred to *A. Dama*, but they are not sufficient to afford a sound basis for the description of the species. The specimens from the Wenlock Shale show a pair of spines springing from the neck-segment, and are clearly distinct from any of the forms here described.

[1] Morris, 'Catalogue of Brit. Fossils,' 2nd ed. (1854) p. 99.

III. Comparison with the Swedish and Bohemian Faunas.[1]

If we compare the British Silurian species of *Acidaspis* with those from the same beds in Bohemia and Sweden, we arrive at some interesting results. The following table includes all the species which have yet been described from the Silurian of Sweden [2] and Britain, and also those from Bohemia which are nearly allied to any of the Swedish or British forms. There are, however, numerous Bohemian species besides these.

In the table the species which are closely allied to each other are placed upon the same horizontal line, so as to show the amount of resemblance between the three faunas :—

Sweden.	Britain.	Bohemia.
	A. Brighti.	*A. Grayi.*†
*A. bicuspis.**	*A. Barrandei*, F. & S.	*A. vesiculosa*, etc.
A. crenata ; *A. Barrandei*, Ang.	*A. crenata.*	
A. coronata (= *A. Marklini*).	*A. coronata.*‡	
A. centrina.	*A. erinaceus.*	
A. pectinata.	*A. callipareos.*†	
	A.	
	A.	
	A.	
A. cornuta.†		
		Numerous other species.

* Only a single fragment of *A. bicuspis* appears to have been discovered.

† I have had no opportunity of examining these species.

‡ *A. coronata* occurs in Germany, but only in the boulders of the Glacial deposits, and these have probably come from Sweden.

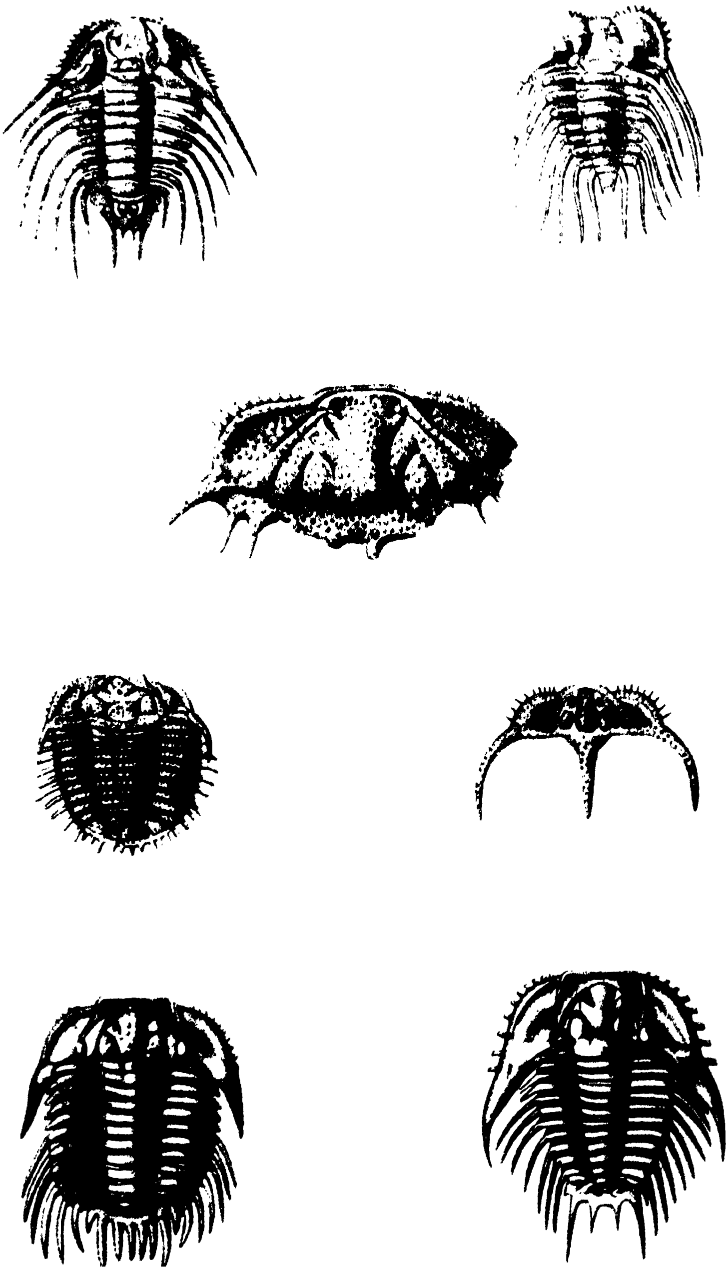
§ The specimen of *A. quinquespinosa* described by Beyrich under the name *A. Brightii* came, not from Bohemia, but from Ludlow.

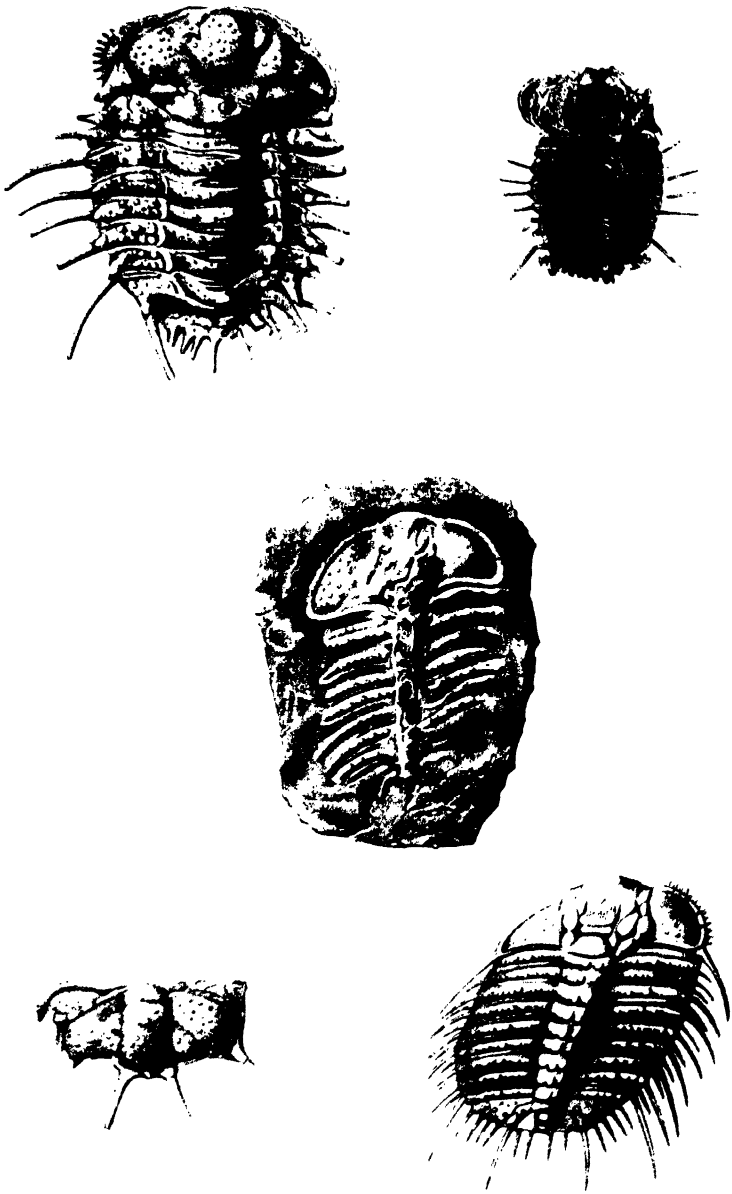
So far, then, as this comparison goes, two species from the British Silurian are represented by closely allied forms in Bohemia, and five in Sweden. There is but one Swedish species represented in Bohemia, of which only a single specimen is known ; and, on the other hand, there is only one which is not represented in Britain. Lastly, there are more species of *Acidaspis* in the Silurian of Bohemia than in the Silurian of Sweden and Britain put together.

These results are suggestive, but they are no more. Until a larger number of species has been examined, it would be rash to draw

[1] I have to thank Prof. Lindström for permission to examine the magnificent series of trilobites in the Riksmuseum at Stockholm, and for much kind assistance during my stay in that city.

[2] See Prof. Lindström's 'List of the Fossil Faunas of Sweden,' edited by the Palæontological Department of the Swedish State Museum (Natural History), pts. i. & ii. Stockholm, 1888. The two species *A. centrina* and *A. cornuta* from the upper 'Brachiopod Schists' are included, since those beds seem to contain a certain number of Llandovery forms.





any conclusions. So far, however, as the genus *Acidaspis* is concerned, it appears that the British Silurian fauna is intermediate between those of Sweden and Bohemia, but more closely allied to the former.

EXPLANATION OF PLATES VII. & VIII.

Plate VII.

Figs. 1 & 2. *Acidaspis crenata*, Emm., sp. Wenlock Beds, Dudley. British Museum (Nat. Hist.). 1. Broad-tailed form, × 2. 2. Narrow-tailed form, × 2.

3 & 4. *A. quinquespinosa*, Salt. 3. Entire specimen, deprived of its test. Wenlock Limestone, Wren's Nest, Dudley. Brit. Mus. Nat. size. 4. Head, with test preserved. Wenlock Limestone, Dudley. Fletcher Collection, Woodwardian Museum. × 2½.

Fig. 5. *A. Brighti*, Murch. Head. Wenlock Limestone, Dudley. Fletcher Coll., Woodw. Mus. × 1½.

6. *A. coronata*, Salt. Wenlock Limestone, Dudley. Museum of Practical Geology, Jermyn Street. × 2.

7. *A. deflexa*, sp. nov. Wenlock Shale, Dudley. Brit. Mus. × 2.

Plate VIII.

Figs. 1-3. *Acidaspis Barrandei*, Fletch. & Salt. Wenlock Limestone, Dudley. Fletcher Coll., Woodw. Mus. 1. The most complete specimen known; anterior and posterior segments partially concealed. Nat. size. 2. Specimen showing internal view, with all the thoracic segments displayed. Nat. size. 3. Head, showing occipital spines. × 1½.

4, 5. *A. Hughesi*, Salt. 4. Salter's type. Casterton Low Fell. Woodw. Mus. × 2. 5. S. of Gale Garth, Casterton. Mus. Pract. Geol. × 2.

Discussion.

The President said that the Author was pursuing the only safe method possible at the present day when working at any special group, namely, to visit the Museums and localities abroad where such specimens are to be studied. Mr. Lake had already visited Sweden, and hoped to study the trilobites of Bohemia. His work would be very welcome to all palæontologists.

Mr. Marr remarked that the Bohemian beds lying between the Ordovician and Devonian were not very rich in trilobites, except those of Upper Ludlow age. He asked whether *Acidaspis erinaceus* was closely related to *A. centrina*, and whether the latter was considered identical with *A. granulata*. He was glad to find that *A. Hughesi* was at last described. Two entirely different species, one Silurian and one Devonian, had been named *A. Hughesi*, with the result that in future fossil lists *A. Hughesi* will probably be recorded as a form passing from Silurian to Devonian.

The Author replied that *Acidaspis granulata*, Ang., was generally looked upon by Swedish palæontologists as a synonym of *A. centrina*, Dalm.

12. *On the* STRUCTURE *of the* PLESIOSAURIAN SKULL. By CHARLES W. ANDREWS, Esq., B.Sc., F.G.S. (Read February 26th, 1896.)

[PLATE IX.]

THE structure of the skull of the Liassic Plesiosauria has been discussed by many writers, but the various accounts that have been given of it are incomplete, and often differ one from the other in important particulars, doubtless owing to the fact that in most cases the specimens examined are much crushed, and are embedded in the matrix, so that only one aspect is visible. In the National Collection there is, however, a fine skull of *Plesiosaurus macrocephalus*, which has lately been almost completely cleared from the matrix, so that it exhibits both the upper and under surfaces; this specimen, though it has been subjected to a slight vertical compression which has caused some fractures and dislocations, gives a fairly clear idea of the general arrangement of the constituent bones, and, since it throws light on some obscure points, seemed worthy of the following brief notice. Certain other specimens, which are of assistance in some difficulties, will also be referred to.

In 1838 Owen[1] figured and described the upper and lateral regions of the skull of *P. macrocephalus*, and in 1881 Sollas[2] described under the name *P. brachycephalus* some portions of the head of a specimen probably referable to the same species. Neither of these writers had an opportunity of examining the palate, and it is this region, therefore, that is more particularly considered here; while, in the structure of the rest of the skull, only such points are noticed as seem to add to, or to be at variance with, the descriptions already published.

The specimen (Pl. IX.) under consideration is from the Lias of Lyme Regis, and was referred to *Plesiosaurus macrocephalus* by Mr. Lydekker.[3] The occipital surface is still somewhat obscured by adherent matrix, and has the anterior cervical vertebræ attached to it, although the atlas has been dislocated from its articulation with the occipital condyle.

The bones of the palate (Pl. IX. fig. 1), though somewhat displaced from their natural positions, are, with the exception of the transverse bone, fairly well preserved and distinct, so that their form and relations can easily be made out.

The basioccipital (*b.oc.*) bears the whole of the nearly hemispherical occipital condyle, and carries on either side a stout, outwardly-directed tuberosity, the truncated end of which looks outward. In the Plesiosauria the whole of these tuberosities is formed by the basioccipital, but in most reptiles the basisphenoid enters into their composition.

[1] Trans. Geol. Soc. ser. 2, vol. v. pt. iii. (1840) pl. xlv.
[2] Quart. Journ. Geol. Soc. vol. xxxvii. (1881) pl. xxiv. fig. 1.
[3] Cat. Foss. Rept. Brit. Mus. pt. ii. (1889) p. 268, no. 49202.

The palatal surface of the basisphenoid (*b.sph.*) rises abruptly from the basioccipital; it is slightly concave from side to side, and is sharply separated from the lateral surfaces, which make an angle of from 100° to 120° with it. The posterior portion of these lateral surfaces forms a facet, looking outward and downward, with which the pterygoid articulates. The basisphenoid seems to have been overlapped by a parasphenoid (*pas.*), but the hinder border of that bone is indistinguishable; anteriorly it expands into a thin, spearhead-shaped plate, the outer angles of which in the present specimen overlap the ventral surface of the pterygoids, and with them limit the posterior palatine foramina (*post.pal.vac.*),[1] which open between the *basis cranii* and the pterygoids, as in *Peloneustes*. In this latter, however, the parasphenoid is slightly overlapped on its ventral surface by the pterygoids; this difference in the relative position of the bones in the two genera may be due to displacement in the present specimen.

The pterygoids (*pt.*) are triradiate bones, like those of *Peloneustes*, but differ from them in not meeting in the median line over the basisphenoid, and remaining separated by the whole palatal width of that bone. Anteriorly they have been dislocated from their junctions with one another and the surrounding bones, but there can be no doubt that in their natural position they met anteriorly and, together with the parasphenoid, closed the palate in the middle line.

Their anterior rami are thin triangular plates, the apices of which meet the vomers, while their inner borders form a median suture with one another in front, and are overlapped by the parasphenoid behind. In the uncrushed skull their outer edges united with the palatines.

The lateral rami run outward opposite the anterior end of the posterior palatine foramina; their outer ends are much thickened and in the present specimen have been partly broken away. In the skull of *P. dolichodeirus* noticed below (fig. 1, p. 248), the outer ends of these lateral rami are joined to the maxillary region by a transverse bone (*trs.*), and the same is the case in *Peloneustes* and *Pliosaurus*.

In front the posterior rami are narrow bars of bone forming the outer border of the posterior palatine foramina. Behind these openings they widen a little, and bear on their inner side facets for articulation with the corresponding surfaces on the sides of the basisphenoid. Posteriorly they run outward and backward as thin vertical plates to the quadrates, which do not appear to send forward to meet them plates of bone such as are seen in *Sphenodon*.

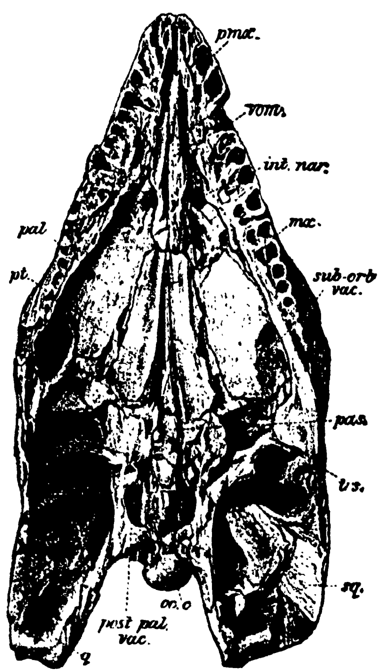
The *columella cranii* (Pl. IX. fig. 4, *col.*) or epipterygoid is well

[1] In this paper, as well as in that on the skull of *Peloneustes* (Ann. Mag. Nat. Hist. ser. 6, vol. xvi. 1895, p. 242), the term 'post-palatine foramen' is used in a different sense from that in which it is sometimes employed (for example, by E. T. Newton in his papers on the Reptilia of the Elgin Sandstones), and is applied to the pair of foramina which result from the division of the median interpterygoid foramen by the basisphenoid and parasphenoid. Newton employs the term for the aperture which lies in front of the transpalatine, and is here called the 'suborbital foramen.'

shown in this specimen. It rises from the upper surface of the pterygoids about opposite their junction with the basisphenoid; its base of attachment is very long from before backward, so that it extends for a considerable distance along the upper edge of the quadrate process of the pterygoid. In its middle portion it contracts in width, and is an elongate oval in section. On both sides of the skull the upper portion of this bone has unfortunately been broken away, so that the junction with the parietals is not clear, but it evidently joined their lower edge at about their middle point.

The palatines (*pal.*) are elongated plates of bone, of which the anterior edges form the hinder margin of the nares; on the inner side they unite in front with the vomers, and behind with the pterygoids, while on the outer they join the maxillæ. In the present specimen the relations of the hinder border of the palatine are not clear, though it is evident that internally it joined the lateral ramus of the pterygoids; but in a skull of *P. dolichodeirus* (B.M. Coll. 41101) it can be seen (fig. 1) that externally the hinder border of the palatine joined the transpalatine for a short distance, and was then separated from it by a small suborbital foramen (*sub-orb.vac.*) which appears to be closed on its outer side by the maxilla. Mr. Lydekker [1] first called attention to these foramina in this specimen (fig. 1), in which also he first observed the fact that the pterygoids extend forward to meet the vomers.

Fig. 1.—*Palatal surface of the Skull of* Plesiosaurus dolichodeirus. (*About ½ natural size.*)



The vomers (*vom.*) are not well preserved; they are long narrow bones which unite, and perhaps anchylose, in the middle line. Posteriorly they join the pterygoids, and in front of these, the palatines. About the middle of their length they form the division between the internal nares, and anterior to these apertures they run forward between the maxillæ and premaxillæ.

[1] Cat. Foss. Rept. Brit. Mus. pt. ii. (1889) p. 257, no. 41101.

The lower surface of the maxillæ and premaxillæ is largely concealed by the mandible, which is tightly closed upon them. The inner border of the palatal plate of the maxilla is, however, visible for some distance both in front of and behind the internal nares, the outer border of which it forms. In its anterior region there are one or two pits which probably mark the points of eruption of successional teeth. The palatal portion of the premaxillæ is almost completely concealed by the symphysial region of the mandible; but the anterior ends of the vomers appear to run forward some distance between these bones: in the above-mentioned skull of *P. dolichodeirus* this is certainly the case (fig. 1, p. 248).

The general structure of the Plesiosaurian palate is shown diagrammatically in fig. 2 (p. 251).

The structure of the temporal arcade (Pl. IX. fig. 3) is, in all essential respects, similar to that in *Plesiosaurus brachycephalus* (figured by Sollas),[1] *P. dolichodeirus*, and *P. Hawkinsi* (figured by Owen),[2] and also to that of *Peloneustes*[3]: the only important difference being that in the present species the postorbital sends back a long thin strip along the anterior ramus of the squamosal nearly to its origin. The supra-jugal which Sollas observed in *P. brachycephalus* cannot be detected, but, if I understand the description of that bone (it is not figured), it corresponds to the lower portion of the postorbital. The thin posterior extension of the maxilla along the lower edge of the jugal is concealed by the mandible, the pressure of which has driven it inwards.

The wall of bone described by Sollas, which separates the orbit from the temporal fossa, is well shown in this specimen. It appears to be mainly formed by the postfrontal and postorbital, each of which thus consists of an external facial and an internal postorbital portion, which meet in the angle forming the anterior rim of the temporal fossa. I cannot make out what share in the formation of this postorbital wall is taken by the jugal; according to Sollas it is an important one.

The upper ramus of the triradiate 'squamosal' is in this specimen indistinguishably fused with the remainder of that bone; but in the younger skull described by Owen it is separated by a distinct suture, which is figured by him.[4] He calls this upper portion the 'mastoid,' while the remainder of the bone, consisting of the inferior and anterior rami, is designated the 'squamosal.' It is clear that these two elements are equivalent to the supra-temporal and squamosal of lizards, according to the terminology of Parker & Bettany and many other writers, or to the squamosal and prosquamosal, according to Baur. Their arrangement is similar to that occurring in the Rhynchocephalia, the fused elements of the older individuals having almost exactly the form and relations of the so-called 'squamosal'

[1] Quart. Journ. Geol. Soc. vol. xxxvii. (1881) pl. xxiv. fig. 2.
[2] Trans. Geol. Soc. ser. 2, vol. v. pt. iii. (1840) pl. xlv.
[3] Ann. Mag. Nat. Hist. ser. 6, vol. xvi. (1895) p. 251, fig. 2.
[4] Trans. Geol. Soc. ser. 2, vol. v. pt. iii. (1840) pl. xlv.

of *Sphenodon.* Koken[1] has expressed the same opinion as to the constitution of the 'squamosal' in the Nothosauria. In several Plesiosaurian skulls in the British Museum the suture between these elements is distinct.

The quadrate (*q.*) is a long, stout bone; posteriorly it is convex from side to side, anteriorly concave. It projects downward and backward, and the condyle for the mandible lies somewhat below the level of the alveolar border of the maxilla. On its outer side the inferior ramus of the squamosal is closely adherent to it, and extends nearly down to the condyle.

In *Cimoliosaurus* Cope[2] has figured a small quadrato-jugal, and Koken[3] has recorded the probable occurrence of this bone in *Nothosaurus*; it therefore seems possible that the Plesiosaurian quadrate may be a fusion of the quadrate and quadrato-jugal, a view which derives some support from the fact that the relations of the squamosal to the 'quadrate' are almost exactly similar to those existing between the squamosal and the quadrato-jugal in *Sphenodon.*

The general structure of the upper surface of the skull is shown in Pl. IX. fig. 2. It will be seen that between the anterior halves of the temporal fossæ the parietals form a high, sharp crest, but that posteriorly they widen out into a broad triangular plate, convex from side to side, which apparently roofs in the brain-case. The outer angles of this plate are overlapped by the upper rami of the squamosals, these forming the hinder border of the temporal fossæ. In front, opposite the anterior end of those fossæ, the parietals enclose the pineal foramen, which does not extend into the frontals, and laterally they widen out and take part in the formation of the postorbital wall. There is clearly a distinct post-temporal fossa, closed above by the lateral process of the parietal and the upper ramus of the squamosal. The frontals extend much farther forward than in *Peloneustes*, and separate the external nares. I can find no clear evidence of the existence of distinct nasals and lachrymals.

Comparison of the palatal portion of this skull with that of *Peloneustes* shows that the chief difference between them is that in the latter the pterygoids, instead of merely articulating with the sides of the basisphenoid, overlap it, and form a median suture with one another on its ventral surface. In *Peloneustes*, also, the form of the parasphenoid is different, and it is very uncertain whether there is any suborbital vacuity.

In *Nothosaurus* the pterygoids meet in the middle line from end to end, and there is no suborbital vacuity, so that the palate is completely closed; this appears to be a more specialized condition than occurs in either *Plesiosaurus* or *Peloneustes*, although both these genera are of a later date.

[1] 'Beiträge zur Kentniss der Gattung *Nothosaurus*,' Zeitschr. deutsch. Gesellsch. vol. xlv. (1893) p. 363.

[2] 'On the Structure of the Skull in the Plesiosaurian Reptilia,' Proc. Amer. Phil. Soc. Philadelphia, vol. xxxiii. (1894) p. 110.

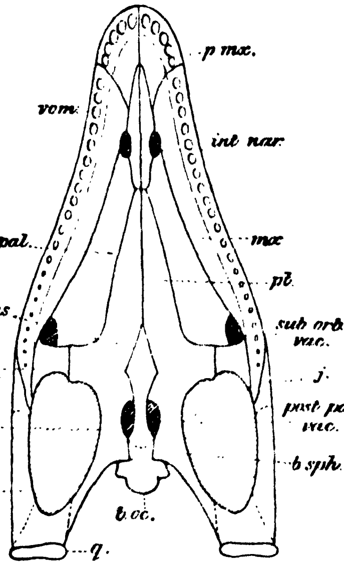
[3] *Op. supra cit.*

In *Lariosaurus*[1] the palate is essentially similar to that of *Plesiosaurus*, but here again the pterygoids completely shut in the *basis cranii*. The suborbital vacuity is very large, and the pterygoids bear teeth, both probably primitive characters. The palate of *Neusticosaurus* is doubtless similarly constructed, but the suborbital vacuities are still larger.

In *Pistosaurus* the pterygoids appear to leave the *basis cranii* exposed for some distance, and in this respect the palate in this genus is more Plesiosaurian in form than is that of any other Triassic Sauropterygian.

Among reptiles other than the Sauropterygia the palate most similar to that under consideration is found in *Sphenodon*. In this reptile the form and the relations of the bones of the palate to one another and to the internal nares are almost identical with those above described. The only difference of importance is that the pterygoids, instead of articulating directly with the sides of the basisphenoid, are borne off from it by downwardly-directed basi-pterygoid processes, so that they come to lie at a lower level than the *basis cranii*. The consequence of this arrangement is that the parasphenoid, here very small, does not run forward between them dividing the interpterygoid vacuity into two post-palatine foramina.

Fig. 2.—*Diagrammatic figure of the Plesiosaurian palate.*



Too much importance must not be attached to the similarity existing between the palates of these two forms, since the Rhynchocephalian type of palatal structure occurs in a more or less modified form in many widely divergent reptilian groups, and probably therefore approaches the primitive type of structure common to the ancestors of those various groups. For instance, the Ichthyosaurian palate, except that the lateral wing of the pterygoid is reduced, and the transverse bone consequently absent, is very like that of *Sphenodon*. Again, among the Anomodonts, *Procolophon* is, so far as the palate is concerned, Rhynchocephalian; the presence of teeth

[1] For my knowledge of the structure of the palate in this genus I am indebted to Mr. Boulenger, who kindly allowed me to see a proof of his forthcoming paper on the skeleton of *Lariosaurus Balsami*.

on its pterygoids and vomers is probably a primitive character derived from its Labyrinthodont ancestors; the palate of *Pareiasaurus* is similar.

In the Theriodonts a short secondary hard palate is developed, carrying back the opening of the internal nares; but in some specimens (for example, the skull of *Galesaurus planiceps*, B.M. R. 511) the relations of the bones constituting the primitive palate are *Sphenodon*-like, the pterygoids extending forward to meet the vomers, and their lateral rami bearing a downwardly-directed process (ectopterygoid) which lies against the inner side of the closed mandible, and is no doubt partly formed by a transpalatine element. There seems to be no suborbital vacuity.

The palatal structures of the Chelonia, regarded as modifications of the same type, are easily comprehensible, and the same is the case with the Lacertilia. In the highly specialized palate of the Crocodilia, the resemblance to the primitive form is masked by the secondary hard palate formed by the palatines and pterygoids; but if this be disregarded, the same type of structure may be traced here also.

Enough has been said to show that among reptiles a certain similarity of palatal structure does not necessarily imply any close relationship, but the very great resemblances existing between the Plesiosaurian and Rhynchocephalian palates, reinforced by the numerous other points of likeness in other portions of their skeletons pointed out by Baur, lead to the conclusion that the Sauropterygia, notwithstanding their single temporal arcade and thecodont dentition, are descended from a primitive Rhynchocephalian reptile. This opinion has already been expressed by several writers, notably by Baur [1] and Boulenger.[2]

EXPLANATION OF PLATE IX.

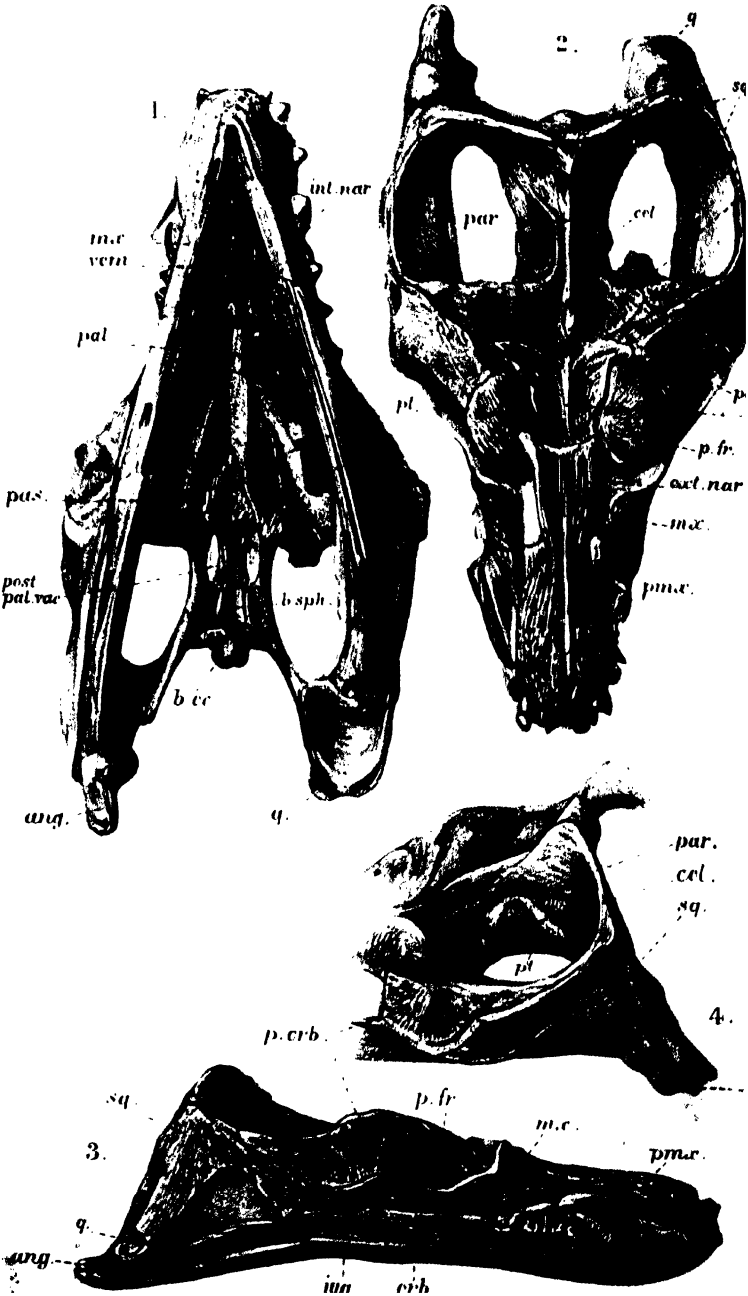
Skull of *Plesiosaurus macrocephalus*, Buckland.

Fig. 1. From below.
2. From above.
3. From the side.
4. Temporal fossa seen obliquely from the side, showing the relations of the *columella*.

ang., angular.
b.oc., basioccipital.
b.sph., basisphenoid.
col., columella cranii.
ext.nar., external nares.
int.nar., internal nares.
fr., frontal.
jug., jugal.
mx., maxilla.
orb., orbit.
pal., palatine.
par., parietal.
pas., parasphenoid.
pin.for., pineal foramen [misprinted *pm.for.*].
pmx., premaxilla.
p.orb., post-orbital.
p.fr., pre-frontal.
? *post.fr.*, ? separate post-frontal.
post.pal.vac., posterior palatine vacuities.
q., quadrate.
sq., squamosal.
vom., vomer.

All the figures are about ½ natural size.

[1] 'On the Phylogenetic Arrangement of the Sauropsida,' Journ. Morph. vol. i. p. 93.
[2] Cat. Chelonians, Rhynchocephalians, and Emydosaurians in the British Museum, p. 1.


1.
int. nar
mx
vom
pal
pas.
post
pal. vac
b. sph.
b. oc
ang.
q.
2.
q
sq
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ex
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p. fr.
ext. nar
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pmx.
par.
cel.
sq.
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4.
p. orb.
3.
sq.
p. fr
mx.
pmx.
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ang.
ina
orb

Discussion.

The President invited discussion.

Prof. Howes, on behalf of morphologists, gave expression of gratitude to the Trustees and Staff of the British Museum of Natural History for the work now being accomplished in their Geological Department. He remarked that he had been privileged to examine the Author's specimens, and that he fully confirmed his determinations. He could not accept the idea, to which reference had been made, that *Pareiasaurus* had a closed palate in the ordinary sense; that is to say, the internal nasal openings were not carried to the back of the palate by the union of the palato-pterygoid bones as they are in the Crocodilia.

In concluding, he pointed out that the Author's determinations of the bony palate of the Sauropterygia were in complete harmony with Mr. Lydekker's of that of the Ichthyopterygia, and with the best-established facts of morphology; and that, thanks to these gentlemen, we were now in a position to definitely refer the 'Enaliosauria' to an origin among the lowest reptiles.

Mr. Lydekker and Dr. Woodward also spoke.

The Author expressed his thanks to the Fellows, particularly those who had spoken, for the kind manner in which they had received his paper. He also referred to his indebtedness to Mr. Hall, one of the 'masons' at the Natural History Museum, for the skilful way in which he had cleared the specimen from its hard matrix.

13. *On the* Morte Slates, *and* Associated Beds, *in* North Devon *and* West Somerset.—Part I. By Henry Hicks, M.D., F.R.S., P.G.S. (Read February 5th, 1896.)

[Plates X. & XI.]

Contents.

I. Introduction.

Hitherto the Morte Slates have received but scant attention from geologists, owing to the fact that in all text-books, and in geological papers on North Devon, they have always been referred to as unfossiliferous; and all that was known with regard to them up to the year 1887 is well summarized in the following paragraph taken from the second edition of Mr. H. B. Woodward's well-known work, 'The Geology of England and Wales,' p. 127:—'This division, termed the Morte Slates by the Rev. D. Williams, derives its name from Morte Point, on the north-west coast of Devon. The term Mortehoe Group, from the village of that name, was used by John Phillips. The Morte Slates, or "grey slates," comprise pale greenish-grey and silvery grey glossy slates, much veined with quartz, and having a thickness estimated at from 3000 to 4000 feet. No fossils have been found; nor have any limestone-bands been recognized in them. The beds rest on the Ilfracombe Beds at Lee Bay, and the subdivisions which can be traced are noted by Mr. Etheridge (in ascending order) as the Lee, Rockham Bay, and Morthoe Beds. The Morte Slates pass downwards into the Ilfracombe Beds, and in Mr. Ussher's opinion they are simply an upper unfossiliferous portion of this lower division, since it is impossible to fix any definite boundary between them. Simonsbath is situated in the valley of the Barle, between the Ilfracombe and Morte Beds. Eastwards they extend to near Wiveliscombe, where they are exposed at the Oakhampton Slate quarry, north of that town. The slaty beds of Hestercombe, north of Taunton, are probably on the horizon of the Morte Slates. The valuable spathose iron-ore of the Brendon Hills occurs in these beds.'

On November 26th, 1890, I read a paper before this Society 'On the Rocks of North Devon,' in which I stated that during a recent visit to North Devon not only had I found that the Morte Slates were fossiliferous, but that I had come to the conclusion that they were the oldest rocks in the area, and that they had, as the result of movements in the earth's crust, been brought to the surface and thrust over much newer rocks, producing a deceptive appearance of overlying the latter conformably.

As my views regarding the succession were strongly controverted at the time, the paper was withdrawn, and I decided to re-examine the area, and to carry my researches into other districts which I had not previously had an opportunity of visiting. As this has necessitated the spending of several weeks each year, since the paper was read, either in North Devon or West Somerset, much additional evidence bearing on the succession has been obtained; but in this that relating mainly to the position and age of the Morte Slates will be referred to.

The beds included under the term 'Morte Slates' are for the most part much folded and highly cleaved, and the fossils are in consequence frequently much distorted and in a bad state of preservation. A considerable amount of labour and time has therefore had to be expended on these rocks to obtain anything like a satisfactory fauna. The results on the whole, however (when it is remembered that up to 1890 these beds were always referred to as unfossiliferous), must be considered as highly important, since we are now able by the aid of the fossils to define the age of a very considerable portion, if not of the whole, of these beds. That they must necessarily furnish the clue by which the succession in North Devon is to be unravelled will, I think, be generally admitted. Therefore, if their geological horizon can be settled the main difficulties which have so long surrounded the 'Devonian question' in North Devon, and which have led to so much controversy in the past, will virtually disappear.

In the geological map given in Mr. Etheridge's very important paper published in this Journal in 1867, the Morte Slates are shown as extending continuously from Morte Point to near Wiveliscombe, in West Somerset, a distance of over 40 miles. That rocks which possess characters resembling in many ways the typical Morte Slates are to be found all along this line there can be no doubt, but it will be shown that, here and there, they vary much in appearance and belong to different geological horizons. The strike of the beds also changes, and is seldom quite parallel with the overlying strata.

In my search for fossils in these rocks I have received invaluable assistance from my friends the Rev. G. F. Whidborne, M.A., F.G.S., and Mr. J. G. Hamling, F.G.S., of Barnstaple. I have also to express my indebtedness for special assistance with regard to some of the fossils from Mr. Sharman and Mr. Allen, of the Museum of Practical Geology; Mr. Bather, of the British Museum (Natural

History); Mr. F. Cowper Reed, of Cambridge; Mr. J. Hopkinson, and Prof. C. Lapworth.[1]

[1] [A complete *résumé* of the literature of the North Devon rocks up to the year 1867 has been given by Mr. Etheridge in his paper already referred to. Up to the year 1868 the views put forward by Sedgwick, Murchison, Godwin-Austen, De la Beche, and Phillips received general acceptance, but during that and subsequent years Prof. Jukes suggested modifications which tended towards a very different interpretation. In his paper in the Quart. Journ. Geol. Soc. in 1866, vol. xxii., he says at p. 321: 'As I shall have to maintain that all the first geologists of the day, including Prof. Sedgwick, Sir R. I. Murchison, Mr. Weaver, Sir H. De la Beche, and Prof. Phillips, have misunderstood the structure of the country, let me hasten to avow my belief that nobody whose observations were confined to Devon and Somerset could have arrived at any other than their conclusions. I fully admit that the rocks near Lynton appear to be the lowest, and that there appears to be a regular ascending succession of rock-groups from Lynton to the latitude of Barnstaple. I am, however, compelled to dispute the reality of this apparent order of succession, and to suppose that there is either a concealed anticlinal with an inversion to the north, or, what I believe to be much more probable, a concealed fault running nearly east and west through the centre of North Devon, with a large downthrow to the north, and that the Lynton beds are on the same general horizon as those of Baggy Point and Marwood.'

In 1867 Mr. Townshend M. Hall, whose researches have added so much to our knowledge of the North Devon rocks and their fossil contents (Quart. Journ. Geol. Soc. vol. xxiii. p. 371), subdivides the North Devon series, in ascending order, as follows:—Foreland group, Lynton zone, Martinhoe beds, Ilfracombe group, Morthoe group, *Cucullæa*-zone, Pilton beds—and says: 'From the Foreland on the north to Barnstaple on the south the rocks have an almost uniform dip to the south, usually at a high angle, presenting to all appearance an unbroken succession.'

Mr. Etheridge, in his paper of the same year (*op. cit.* vol. xxiii. p. 568), strongly controverts the views put forward by Prof. Jukes, and maintains that the succession in North Devon is one unbroken and continuous series. He subdivides the rocks in ascending order as follows (p. 580):—

Lower Devonian.	*a.* Lynton Sandstone. (Foreland Beds.) *b.* Lynton Slates.
Middle Devonian.	*c.* Hangman Grits. *d.* Calcareous Slates (fossiliferous). (Ilfracombe Beds.) *e.* Grey unfossiliferous slates. (Morte Slates.)
Upper Devonian.	*f.* Pickwell Down Sandstones. *g.* Baggy and Marwood Slates, etc. *h.* Croydon [Croyde] Beds. *i.* Braunton Beds *k.* Pilton and Barnstaple Beds.

He further says at p. 694: 'After very careful investigation into the physical structure of North Devon, as well as a critical examination of the organic remains contained in its diversified rock-masses, I can come to no other conclusion than that the series of sandstones, slates, and limestones ranging from the Foreland and Lynton on the north to Pilton and Barnstaple on the south are one great and well-defined system, and equally well divisible into three groups, a Lower, Middle, and Upper Devonian series, each equally well characterized by a fauna, the zoological facies of which are sufficiently distinct to determine them one from the other.'

The following appears to be the final arrangement suggested by Prof. Jukes; it occurs in a paper read before the Royal Geological Society of Ireland in

II. Morthoe and Woolacombe to Bittadon.

The beds are well exposed at Morte Point and in the cliffs of Rockham Bay on the northern side, and between the Point and Woolacombe on the southern side. At the Point the beds are nearly vertical, being folded so acutely that the bedding, owing to the cleavage, is with difficulty made out. Under Morthoe, however, there are some well-marked folds, and the strike is shown to be from about W.S.W. to E.N.E. The folds are here, as in most places along this

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November 1867, and is given in reply to the papers in the Quart. Journ. Geol. Soc. of that year by Mr. Townshend Hall and Mr. Etheridge.

Southern Area.	Northern Area.
5. Pilton and Barnstaple Beds.	5. Grey unfossiliferous slate. (Morte.)
4. Braunton Beds.	4. Calcareous Slates. (Ilfracombe.)
3. Croyde Beds.	3. Hangman Grits.
2. Baggy and Marwood Slates.	2. Lynton Slates.
1. Pickwell Down Sandstones (red).	1. Lynton Sandstone (red).

Prof. Jukes places the beds, as named by Mr. Etheridge, in parallel columns, with the view of showing that the groups in the one area are merely a repetition of those in the other.

Since that time the rocks have been investigated by Messrs. Valpy, Hall, Champernowne, Ussher, and others; but no important change in the classification suggested by Mr. Townshend Hall and Mr. Etheridge has been attempted by them. In a paper on the 'History of the Classification and Nomenclature of the North Devon Rocks,' in the Trans. Devonshire Assoc. 1879, p. 189, Mr. Townshend Hall says: 'On the whole, as far as North Devon proper is concerned, I believe the following classification is the best that can be adopted for the Devonian beds:—

Upper Devonian.	Pilton Beds. *Cucullæa*-zone (Baggy Point, etc.). Pickwell Down Sandstone.
Middle Devonian.	Morthoe Slates. Ilfracombe Slates and Limestones. Martinhoe or Hangman Grits.
Lower Devonian.	Lynton Beds. Foreland Sandstones.'

And at p. 190, he says:—'It will be found that the North Devon Beds from Lynton to Pilton, though possessing a general dip to the south, are folded into many anticlinals, reducing their apparent thickness very considerably. I know this to be the case at so many different places throughout the area that, until we have a re-survey on the six-inch scale, I fear it will be a hopeless task to attempt to map the exact boundaries of the subdivisions, or to estimate their real thickness.'

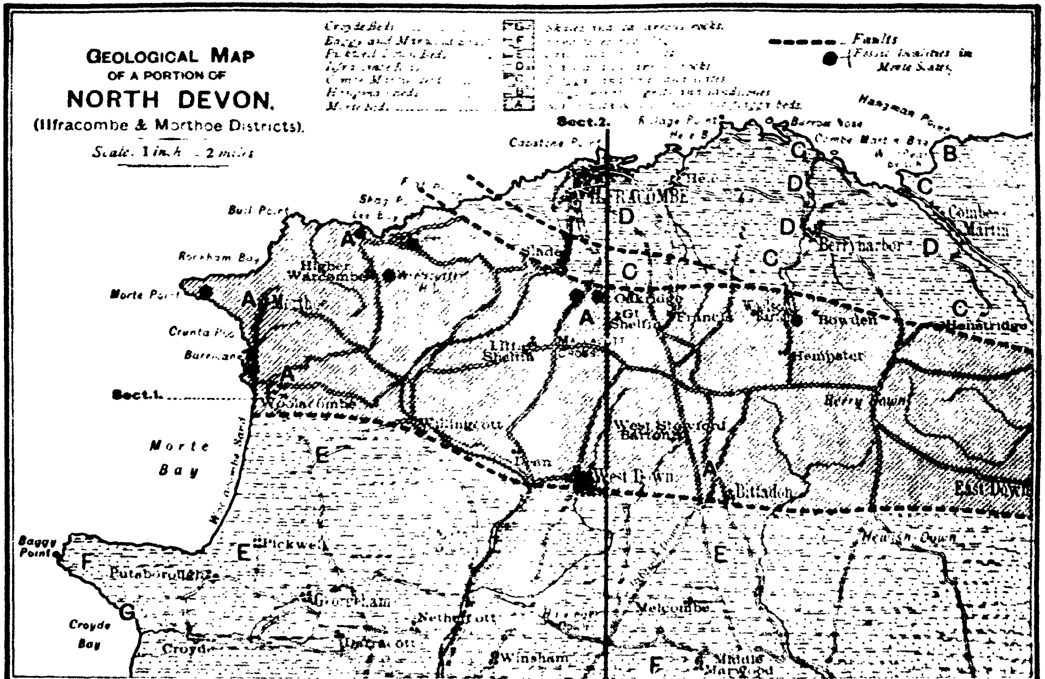
In Sir H. De la Beche's 'Report on the Geology of Cornwall, Devon, and West Somerset,' 1839, a section across the North Devon Beds is given (fig. 1, pl. iii.) which shows several main folds; and Dr. Sorby, in his well-known paper 'On the Origin of Slaty Cleavage' (Edinb. New Phil. Journ. vol lv. 1853, p. 137), and Mr. J. E. Marr, in his important paper 'On some Effects of Pressure on the Devonian Sedimentary Rocks of North Devon' (Geol. Mag. 1888, p. 218), have shown how the rocks in places have been greatly affected and minutely folded and broken by pressure. See also Jukes, Quart. Journ. Geol. Soc. vol. xxii. (1866) p. 371; Champernowne, Geol. Mag. 1878, p. 193; Champernowne & Usher, Quart. Journ. Geol. Soc. vol. xxxv. (1879) p. 532 and Hicks, Geol. Mag. 1893, p. 3.—April 15th, [illegible]

coast, much broken, and the beds near the lines of fractures much seamed with quartz-veins. All the beds are strongly cleaved, and the cleavage-planes are either vertical or with a slight inclination towards the south. There are, here and there, a few thin sandstone-bands, but the majority of the rocks are hard, cleaved slates, and flags of a greyish colour. Where the hard bands occur they are usually much broken by the cleavage, and the broken fragments frequently give to the rocks quite a nodular appearance.

The slates dipping at a high angle can be traced as far south as the Lifeboat House, and also in the bed of the stream at the foot of Challacombe Hill, to a height of about 100 feet. Above this the ground rises rapidly, and a quarry which has been opened for building-stone at a height of about 230 feet, and distant from the last exposure of Morte Beds about 500 feet, shows massive purple, red, and grey grits and sandstones folded and much broken. These, and an exposure close by on Potter's Hill, are the lowest of the Pickwell Down Beds found on the coast, and as they are strongly ripple-marked they must have been deposited in shallow water. Still, their broken condition would indicate a faulted junction at this point. In the quarry one dip is to S.S.E., another to S.S.W., and on Potter's Hill to S.S.E. at 40°. The Pickwell Down Beds extend in an easterly direction, and may be again examined in several quarries on the high ground between here and the Foxhunter's Inn, on the road from Ilfracombe to Barnstaple. Opposite the inn, on the western side of the railway, there is a large quarry, where very massive beds of sandstone are bent into gentle folds, and on the northern side crushed and broken as if near a fault.

The Morte Slates are well exposed in the railway-cutting at Willingcott Bridge, and also at Dean, which is about ¼ mile north of the Foxhunter's Inn. At the latter place they dip northward at about 70°, and differ somewhat in appearance from those exposed at Woolacombe, because a large number of hard bands of a fine-grained sandstone are interstratified with the slates. In following the junction between the Morte Slates and the Pickwell Down Beds up to this point, I could come to no other conclusion than that a fault separated them, and that as a consequence the same beds were very seldom in contact. Beyond West Down, and at Bittadon, the indications of an important fault between the Morte Slates and the Pickwell Down Beds are less marked, and the latter dip to the south at as low an angle as 15° near the inn at Bittadon. I searched carefully at and about Bittadon for evidences of a passage, but everywhere there appeared to be a sudden change from highly-cleaved slates, dipping at a high angle, to massive sandstone-beds with a low dip. It is a marked characteristic of the Morte Series that they are mainly hard, slaty, and flaggy beds made from fine muds, and that the few sandstone-beds are composed of well-rounded grains of quartz in an argillaceous matrix. When compared with the overlying rocks, the almost entire absence of mica is somewhat striking.

The Pickwell Down Beds which, in this area, immediately succeed



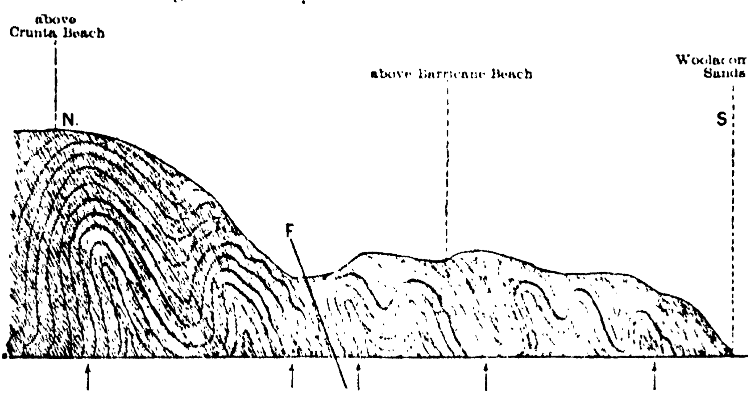
Note.—For 'Mallacott' *read* 'Mullacott.'

the Morte Slates, are characterized by containing angular bits of slate, angular and subangular quartz often stained of a red or chocolate colour, and frequently a considerable amount of a fresh-looking felspar. The sandstones and shales also contain an unusual proportion of detrital mica. When it is remembered that these beds often yield fossil wood, and are frequently ripple-marked, it becomes clear that they were deposited under different conditions from those which prevailed when the majority of the Morte Slates were thrown down, and the evidence certainly points to an important physical change taking place at no great distance about this time.

I have not met with any contemporaneous igneous rocks in the Morte Series, but there are a few intrusive dykes, one of the most important being the felsite at Bittadon described by Prof. Bonney.[1] Others have been referred to by Mr. Etheridge and Mr. Townshend Hall in Morte Bay, Lee Bay, etc.

The Morte Slates in this area yield traces of fossils in many places, but none sufficiently well-preserved for identification, excepting in the cliff-sections at Morthoe and Woolacombe. The first fossil found by me was a *Lingula* at Woolacombe in 1890; but since then several additional genera have been discovered at

Fig. 1.—*Section from near Morthoe to Woolacombe.*



[Horizontal Scale: 6 inches = 1 mile.]

↑ = positions of fossil zones.

Barricane, and in the cliffs at a small creek between Barricane and Crunta Point. They include a *Rhynchonella*, so like *Rh. Lewisii* of the Wenlock rocks that I have no doubt of its being the same species; a small *Spirifer* with a very wide mesial fold and somewhat rough ribs, unlike any British species known to me; and *Orthis rustica*, *Modiolopsis*, encrinites, etc.

[1] Geol. Mag. 1878, p. 207.

At Morte Point, in addition to some large *Lingulæ*, the slates were found to be covered with minute individuals of the same genus, but, as their structure was completely obliterated, very little could be made out of them. In the section (fig. 1) I have marked the positions of the fossil zones, and the folds in the rocks which are to be seen between Morthoe and Woolacombe. The same beds have doubtless been several times repeated, but in some of the broken folds it is probable that there are strata which belong to very different horizons. Moreover, there is a somewhat marked difference in some of the deposits. The flaggy beds which alone enable us to make out the folds are succeeded by fine-grained dark slates, and as these are found at a height of about 500 feet in the hill above Barricane, it is clear that they alone must attain to a thickness of several hundred feet.

III. Rockham Bay, Bull Point, Lee Bay, Lee, and Slade.

Near the centre of Rockham Bay there is a well marked fold in which are some hard, gritty bands, and on the northern side dark bluish-grey slates, which have yielded some small *Lingulæ*, but no other distinguishable fossils. Between here and Bull Point there are indications of another broken fold, and at Bull Point the dip is N.N.W. in striped grey flaggy beds, which exhibit extensive shiny cleaved surfaces. Similar rocks in well-marked folds are found extending along the coast towards Lee Bay. In flags obtained from a quarry on Flagstaff Hill, on the south western side of Lee Bay, I obtained some very large *Lingulæ*. On the eastern side of the same bay are much crushed slates with fucoid-like markings on the surface, and in the cliffs towards Shag Point are greenish and yellowish flaggy beds, sometimes stained of a pinkish colour. Small *Lingulæ* were fairly abundant in some of these beds. Between Shag Point and Flat Point the beds are much broken, and there are clear indications of an important fault. Beyond the fault towards Ilfracombe the rocks are more massive in character, and as they also contain many sandstone-bands, and have not yielded any fossils, I have, for the present, thought it well not to include them with the Morte Series. They are also separated from the typical Ilfracombe Beds by a fault, which extends along the depression between Langley and the coast. These beds are well exposed in the Slade quarry, dipping S. at a high angle at its western end, and folding round to the N. at its eastern end, where there are beds of reddish and yellowish sandstones. These rocks call to mind some of the Pickwell Down sandstones and shale-beds; but it must be admitted that at present their age, owing to the absence of fossils, is indeterminable. In the Lee valley I found a few *Lingulæ* and fragments of encrinites at several points in the Morte Series, and in the quarry opposite the hotel small *Lingulæ* are as abundant as at Morte Point.

IV. Mullacott, Shelfin, and Ilfracombe.

The discovery by me in 1891 of a fairly rich fauna in a quarry on Mullacott Farm, having a strong Silurian facies, led me to make a careful examination of the boundary-line between the Morte Series and the Ilfracombe Beds in this area, and to note any special changes visible in the beds near the junction. During this examination it soon became apparent that there was no gradual passage between the Ilfracombe Beds and the Morte Slates, as had previously been maintained to be the case, but that there was everywhere an important petrological difference to be noticed, which could only be the result of beds of very different age being brought into contact either by a fault or an unconformity. To enable me to make out what was really the cause of this abrupt change, I found it necessary to trace with care the Ilfracombe Beds to the north in coast-sections and in the valleys about Ilfracombe, and evidence was soon obtained to show that where beds had been indicated as dipping regularly to the south, and hence under the Morte Slates, they as often dipped in the opposite direction, that they were bent into a series of acute folds, and that the strong cleavage had often been mistaken for bedding-planes. After this it became possible to follow certain well-marked beds through the various folds, and to make out that these rose up higher and higher in the sections as we approached the Morte Slates, and indicated the southern edge of a well-marked trough, as shown in fig. 2. Further examination revealed the fact that there was marked evidence of much crushing where the Ilfracombe Beds were in contact with the Morte Slates, and therefore that the line of separation here, at least, was an important thrust-fault.

Much of the evidence, so far as it relates to the Ilfracombe Beds, has already been given by me in a paper in the Geol. Mag. for 1893, therefore it is only necessary now to refer to that portion of the evidence which more particularly explains the nature of the junction between the Ilfracombe and Morte Beds. The Ilfracombe Beds are often much broken by faults and frequently inverted, but there are well-marked petrological and palæontological horizons which enable the beds, even when most disturbed, to be identified: therefore, though beds at different horizons are occasionally brought into contact with the Morte Slates, the line of junction, when these facts are borne in mind, can be, as a rule, easily traced.

In Mullacott Hill there is very little superficially to mark the fault-line, but just above Score, in a quarry worked for road-metal, some massive sandstone-beds of the Ilfracombe Series, though in a greatly crushed condition, are seen dipping away from the Morte Beds. North of Great Shelfin the fault runs along a narrow valley, the hill on the northern side being formed by the basal sandstones of the Ilfracombe Series, and that on the southern side by the Morte Beds. In an easterly direction the fault crosses the Oakridge, and afterwards extends through the valley which runs nearly east and west, north of Bowden.

The sandstones of the Ilfracombe Beds remind one much more

strongly of the Pickwell Down Sandstones than of any found in the Morte Series, and, like the former, they contain an abundance of detrital mica. The slaty beds in the Ilfracombe Series also are often highly micaceous. It is necessary to bear these facts in mind, for though on the northern side of the Ilfracombe trough, as at Combe Martin and the Hangman Hills, the beds are as little changed as they are on Pickwell Down, yet on the southern side, near the great fault, they are often so much crushed and broken that the superficial likeness is not at once evident. Moreover, the lowest beds are nowhere seen in this area. On Mullacott Hill there are several quarries which have yielded fossils, but that which has yielded most specimens is on the right side of the road leading from Ilfracombe to Morthoe Station, and less than ¼ mile south of the Ilfracombe Cemetery. The beds of purplish, greenish, and yellowish slates dip at an angle of about 70° to E.S.E. On the northern side of the quarry large *Lingula* are fairly plentiful, but the majority of the other fossils were found in the beds on the southern side. They comprise *Stricklandinia lirata* (some specimens of very large size), *Orthis rustica*, *Rhynchonella Stricklandi*, a new *Pterinæa*, *Cardiola interrupta* (?), encrinites, fragments of a crustacean, etc. The horizon indicated seems to be the base of the Wenlock. In the valley east of this quarry, which separates the Mullacott from the Shelfin ridge, there are several outcrops of the slates, and these have also yielded fossils, chiefly *Linguli*. In some quarries in Shelfin Wood, on the northern side of the Shelfin ridge, the slates are covered with markings resembling graptolites in a bad state of preservation. The other fossils found along with these are a few *Linguli*, one or two specimens of *Stricklandinia lirata*, and fragments of encrinites. In searching for fossils in the Morte Slates it must always be

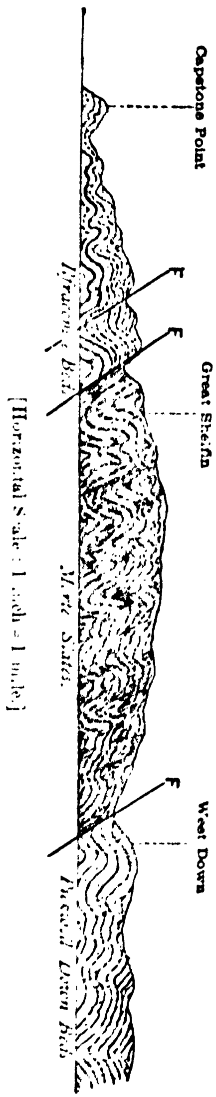


Fig. 2.—*Section from Capstone Point, Ilfracombe, to West Down.*

remembered that the beds are much folded, and that fossils can only be found in anything like a fairly well-preserved state in the limb of the fold where the cleavage-lines and bedding-planes are nearly parallel. In the arch of the fold the fossils are much crumpled, and where the cleavage crosses the beds fragments only are found, though a sharp blow directed in the line of the bedding, which is usually much less marked than the cleavage-line, will sometimes reveal a better specimen. Eastwards from this point the Morte Slates are frequently exposed in small quarries and roadside sections, but there are no quarries of any importance until we reach the neighbourhood of Francis and Woolscott Barton. In the Francis quarry are some thick beds of a yellowish shale, unlike the usual Morte Slates, and, as they have not yielded any fossil evidence other than worm-tracks and doubtful encrinites, there is nothing to guide one as to their proper horizon.

V. Woolscott Barton, Smithson, and Berry Down.

On Woolscott Barton Farm there are several old quarries in the Morte Slates, but in none of these could I find more than traces of fossils. In the slate-quarry in Smithson Wood, on the eastern side of the valley which separates the Woolscott and Smithson farms, many markings resembling graptolites were found on the surface of the slates, also a few small *Lingulæ*, a small *Orthis*, and fragments of encrinites. The slates are of a dark-bluish colour and well cleaved. Similar slates are found in the road-cutting leading to Smithson Farm. In the valley a short distance south of the adjoining farm of Hempster I noticed some light-coloured felstone-dykes cutting through the slates. At Berry Down the Morte Slates rise to a height of over 850 feet, but there are no quarries here of any importance. On the road from Berry Down to Combe Martin the line of separation between the Morte Slates and the Ilfracombe Beds occurs near Henstridge, and the fault runs up the valley which extends for some distance in a nearly east-and-west direction. Sandstones are found in the southern side of Stoneditch Hill underlying the slaty and calcareous beds of the Ilfracombe Series, which are much folded here, as at Ilfracombe. Evidence that the Ilfracombe Beds lie in a wide trough becomes perfectly clear in tracing the sections towards Combe Martin, and identifiable fossils are to be found at several points. The fossils here are, on the whole, in a better state of preservation than near Ilfracombe, and the facts seem to point to a diminishing intensity in the folding and shearing in an eastward direction.

VI. Summary of the Stratigraphical Evidence in North Devon.

It may be well briefly to summarize the results given in this paper, though any conclusions arrived at in regard to the general

succession of the rocks in North Devon will come in more appropriately after the second part of the paper, which will contain the evidence obtained from other areas, has been read before the Society.

The changed position now given to the Morte Slates removes one of the greatest difficulties experienced by previous writers in their attempts at correlating the strata in North Devon with those in other areas, for nowhere else had such a thick series of well-cleaved slates been met with at the horizons assigned to them here. The horizons necessarily varied in accordance with the views in regard to the succession held by the authors. Those who held with Prof. Jukes that there was but one group in North Devon of sandstones, slates or shales, and calcareous beds, repeated by faults, found it necessary to place the Morte Slates at the top of the whole series; while those who claimed that there were two or more series of somewhat similar sediments conformable to one another placed them not far from the centre in the succession. There is good evidence at many points to show that Prof. Jukes was correct in claiming a faulted junction between the Morte Slates and the Pickwell Down Beds, but the results produced by the faults are different from those which he suggested; for, instead of one great broken trough with the Pickwell Down Beds coming up from under the Morte Slates, we find the former resting upon the latter, the faults between being due to crushing during the movements which brought the Morte Slates and the Pickwell Down Beds to the surface.

Until the thrust-fault between the Morte Slates and the Ilfracombe Beds on the northern side had been made out, the only way by which a repetition of the beds could have taken place would be by a great fault on the southern side; but this would necessitate a much greater displacement of the beds than by that which is now known to occur on the northern side of the Morte Slates.

The discovery of fossils in the Morte Slates belonging to several horizons in the succession, and some probably as low in position as the base of the Silurian (Upper Silurian of the Geological Survey), added to the stratigraphical evidence, enables us now to speak with confidence as to their place in the succession in North Devon. They are the oldest rocks in the area, and they do not appear to contain amongst them any beds newer than Lower Devonian. In some places newer rocks may occur amongst them as the results of faults or unconformities, but not in order of succession.

In the second part of the paper evidence will be given to show that in at least one of the areas examined there appears to be a passage from some of the Morte Slates to Lower Devonian rocks containing so characteristic a fossil as *Phacops (Cryphæus) laciniatus*. These passage-beds lie on the southern side between fairly typical Morte Slates and Pickwell Down Sandstones, and in the latter, quite near one of the junctions, we discovered a band rich in fossil wood, and other evidences indicating that they had been deposited near land. When an interpretation of the succession in North Devon and West Somerset, in accordance with the evidence

recently obtained, is submitted, I think it will be seen that it agrees far more closely with that which has been made out in other areas in the British Isles than has hitherto been suspected.

VII. Description of the Fossils found in North Devon.

Lingula mortensis, sp. nov. (Pl. X. figs. 1–5.)

This is probably the largest *Lingula* yet found in the British Silurian rocks, and it occurs very plentifully in the Morte Slates, though usually in a distorted condition. Elongated oval, the sides nearly parallel. Rather acutely rounded in front, and tapering gradually backwards towards the beak. Valves compressed, and surface marked with numerous fine lines of growth, which here and there are sculptured with cross markings.

Length 24, width 9 lines.

In size and shape it more closely resembles *L. Brodiei*, Davidson, from the Woolhope Limestone, than any other species described from the British Palæozoic rocks; but it is larger than that species, and longer in proportion to the width. As one specimen only of *L. Brodiei* has been figured and described, it is possible, when others have been discovered, that they may be found to agree more closely with our shell, especially as they occur on the same geological horizon. In association with the large forms there are others of various sizes, and some of the surfaces are thickly covered with minute specimens as in Pl. X. fig. 5.

Found at Woolacombe, Morte Point, Lee, Mullacott, and Shelfin.

Stricklandinia lirata, Sowerby. (Pl. X. figs. 6–8.)

This is the most characteristic fossil in the Mullacott quarry, but though it occurs there in fair abundance it is most difficult, owing to the crushing and cleavage, to obtain any good specimens. Those, however, which have been found show that it attained a large size, equalling nearly the largest forms found in the Wenlock Beds of the Island of Gothland.

According to Davidson, *Stricklandinia lirata* 'varies greatly in its external shape... The size and regularity of the ribs are especially variable in different specimens, as well as the length of the hinge-line.' (Monogr. Pal. Soc. 'Brit. Sil. Brachiop.' vol. iii. pt. vii. p. 161.)

The suggestion first made to me by Mr. Sharman, of the Museum of Practical Geology, that our fossil seemed more closely allied to *S. lirata* than to any other brachiopod with which he was acquainted, tempted me to make an examination of many of the specimens in our museums; and the fact, stated by Davidson, of its tendency to vary greatly in shape and ornamentation I found very true. I cannot say that, so far, I have been able to exactly match our fossil with any other specimen, but undoubtedly it approaches most closely in its size and ornamentation the specimens in the Society's Museum and in the Jermyn Street Museum, from the lowest beds of Wenlock age at Marloes Bay, Pembrokeshire, and those from Gothland in the Natural History Museum. The following characters, abstracted from those

given by Davidson in the full description in his memoir, published by the Palæontographical Society, vol. iii. pt. vii. p. 159, can be made out in our specimens :—'Transversely oval ; hinge-line nearly straight and shorter than the width of the shell . . . sides and front rounded. Valves moderately convex. Dorsal valve more or less semicircular and trilobed, from the presence of a rather wide mesial fold of small elevation which, commencing at the extremity of the umbonal beak, gradually widens as it approaches the front. Surface of valves ornamented with numerous angular, irregular, often bifurcating ribs, and concentric lines of growth. Near the umbo of the dorsal valve are two elongated pear-shaped impressions, due to the adductor or occlusor muscles, divided in the middle by a central ridge. Numerous pits (rough tubercles on the cast), probably ovarian markings, surround these scars.' The specimens are so much compressed, and also drawn out of shape by the cleavage, that it was only by the examination of a large number that all these points could be clearly made out. There can, however, be no doubt that the fossil is either *S. lirata* or a very closely-allied species. It is an important fossil in defining the horizon, and the other fossils

Fig. 3.—*Impression of* Stricklandinia lirata *from Mullacott Quarry.* (*Natural size.*)

[Reproduced from a photograph.]

found in the same quarry are such as would be expected to occur with it in beds of Lower Wenlock age.

Found in the Mullacott and Shelfin quarries, near Ilfracombe.

RHYNCHONELLA LEWISII (?), Davidson. (Pl. XI. figs. 1–4.)

Many specimens of this species have been found in the rocks on the side of the path leading down to Barricane Beach, but, like most of the fossils found in the Morte Slates, usually in a greatly distorted condition. The specimens have also for the most part lost the ornamentation characteristic of this species, but traces of it are sometimes left in some of them. The pinched appearance of the mesial fold is still retained, and the number of ribs in the mesial fold and sides agrees exactly with those in the Shropshire specimens from beds of Wenlock age. On p. 180, *op. cit.*, Davidson says that 'the range of this species is said to be in the Llandovery and Wenlock rocks; I am, however, acquainted with the shell only from the last-named formation, in which at some localities it is exceedingly abundant.' Hitherto the only locality in the Morte Slates in which it has been found by us is at Barricane in Morte Bay, in association with *Spirifera Hamlingii*, *Lingula mortensis*, etc. Mr. Bather was kind enough to compare our specimens with those in the Natural History Museum, and said that they agreed more closely with the typical specimens of *Rh. Lewisii* in the National Collections than with any other species.

RHYNCHONELLA STRICKLANDI (?), Sowerby. (Pl. XI. fig. 11.)

A few imperfect specimens of this species have been found in the Mullacott quarry. In size and shape the shell agrees with those which occur in the Wenlock Limestone and Shale in other areas. It has a very convex form, is from 12 to 15 lines in length, and the surface is ornamented with from 25 to 30 narrow, simple, angular ribs.

SPIRIFERA HAMLINGII, sp. nov. (Pl. XI. figs. 5 & 6.)

The specimens are compressed and distorted, but they show that the shell was wider than long and moderately convex. The hinge-line is nearly straight, rather longer than the width of the shell, and somewhat pointed at the cardinal angles. Dorsal valve convex, with a well-raised, wide, mesial fold. Surface of valves ornamented with about 36 moderately strong rounded ribs, of which nearly a third occur on the mesial fold. They are frequently crossed by fine concentric lines, and here and there the larger ribs appear to be ornamented with fine lines more or less parallel with them. Area narrow.

Found at Barricane, in Morte Bay.

ORTHIS RUSTICA, Sowerby. (Pl. XI. figs. 7–10.)

This species occurs in fair abundance in the Mullacott quarry, and a few specimens have also been obtained from the rocks on the northern side of Barricane Beach. In each place they are much distorted, but they show the characteristic ornamentation mentioned by Davidson. He says at p. 239 (Monogr. Pal. Soc. 'Brit. Sil. Brach.')

that 'I must now again remind the student that one of the chief characteristics of *Orthis rustica* consists in its generally having a small interpolated rib between each two of the longer ones, or between those which extend directly from the extremity of the beaks to the margin, the number of ribs varying according to the age of the individual.' Among the specimens collected at Mullacott there are examples of all sizes, and some quite as large as the largest found in the Wenlock rocks of Shropshire. Its association here with *Stricklandinia lirata* is highly interesting, and important in defining the horizon of the beds; with the exception of *S. lirata* and *Lingula mortensis*, it is about the most plentiful fossil in these beds.

Found at Mullacott and Barricane.

MODIOLOPSIS BARRICANENSIS, sp. nov. (Pl. XI. figs. 14 & 15.)

This species approaches more nearly in shape *Modiolopsis subalatus*, Hall, of the Niagara Group, than any British species. It is, however, a much larger form than the American species, and the umbo is situated nearer the anterior extremity.

Length about 14 lines, greatest width about 7 lines. Subrhomboidal in shape, posterior side greatly expanded. Anterior extremity short and rounded. Umbo prominent. Surface marked with moderately strong concentric lines, and near the anterior end the concentric lines are crossed by numerous fine lines which extend to the margin.

The shell is still convex near the umbo, but it has evidently been much flattened by pressure.

Found in the cliffs on the northern side of Barricane, and Mullacott quarry.

PTERINÆA MORTENSIS, sp. nov. (Pl. XI. figs. 16, 17.)

Several specimens have been found in the Mullacott quarry, which exhibit characters sufficiently marked to indicate a new species differing in several particulars from any other known British form. The specimens are crushed and evidently somewhat distorted, but show that the shell must have been broader than long, with a nearly straight hinge-line. Anterior wing short and pointed, and separated from the central part of the shell by a sulcus. Posterior wing long and obtusely pointed. The surface of the shell is marked by numerous radiating striæ, which bifurcate as they approach the margin. Some specimens show traces of concentric lines of growth. The umbo is prominent, and situated about a third of the distance from the anterior extremity.

Width 16, length 10 lines.

Found, up to the present, only in the Mullacott quarry.

AVICULA, sp. (Pl. XI. fig. 18.)

No perfect specimens have been found, but the fragment figured shows that it is distinct from any British species. It, however, somewhat closely resembles one of the species (*Avicula undata*) from the Niagara rocks of America.

Found in the cliffs, northern side of Barricane.

EXPLANATION OF PLATES X. & XI.

Plate X.

Figs. 1–4. *Lingula mortensis*, sp. nov. 3ᵃ. Enlarged portion of shell, showing ornamentation. Fig. 5. Probably young specimens of the same species. Mullacott, Shelfin, and Morte Point. Author's Collection.

Figs. 6–8. *Stricklandinia lirata*, Sowerby. Mullacott Quarry. 6, Collection of the Rev. G. F. Whidborne; 7 and 8, Author's Collection.

Figs. 9, 10. *Crania*, sp. Mullacott Quarry. Author's Collection.

Plate XI.

Figs. 1–4. *Rhynchonella Lewisii* (?), Davidson. Barricane, in Morte Bay. Author's Collection.

Fig. 11. *Rhynchonella Stricklandi* (?), Sowerby. Mullacott Quarry. Author's Collection.

Figs. 5 & 6. *Spirifera Hamlingii*, sp. nov. Barricane, in Morte Bay. Author's Collection.

Figs. 7–10. *Orthis rustica*, Sowerby. Mullacott Quarry. Author's Collection.

Figs. 12 & 13. *Stricklandinia*, sp. Mullacott Quarry. Author's Collection.

Figs. 14 & 15. *Modiolopsis barricanensis*, sp. nov. Barricane, in Morte Bay, and Mullacott Quarry. Author's Collection.

Figs. 16 & 17. *Uterinaa mortensis*, sp. nov. Mullacott Quarry. Author's Collection.

Fig. 18. *Avicula*, sp. Barricane. Author's Collection.

Fig. 19. *Cardiola interrupta* (?), Sowerby. A fragment, much enlarged. Mullacott Quarry. Author's Collection.

Fig. 20. A fragment of a Crustacean (carapace?). Author's Collection.

Discussion.

The President said that six years had elapsed since the Author attacked the problem of the rocks of North Devon and their succession. On the former occasion he obtained a verdict of 'not proven.' After further careful work on these beds, the Author now came forward with additional evidence from the field and from the fossils derived from the rocks to prove that his reading of the succession of the Devonian rocks is the true one. He (the President) invited discussion (1) on the stratigraphical, and (2) on the palæontological evidence.

Prof. Hughes believed that the thickness of the several divisions of the Devonian had been greatly exaggerated, and that the vertical distance of the beds, now proved by Dr. Hicks to be fossiliferous, from the known fossil-bearing beds of Hele, for instance, was not really great. He thought that, although the lithological difference between the main mass of the Morte Beds and of those which occurred on either side of it was very great, there were alternations of the sandy and slaty type in the contiguous strata. In so disturbed an area faults would be apt to occur where rocks of unequal resisting-power were crushed together, and this, with the overfold of the anticlinal arches, might give a deceptive appearance of an unconformable junction. The proof of the theory proposed by the Author depended chiefly upon the palæontological evidence. Taking the more important test-fossils laid upon the table, namely, *Cardiola interrupta*, *Stricklandinia lirata*, and the

graptolites, he thought that the first was an imbricated shell, like an *Atrypa*, perhaps *A. aspera*, but that it certainly did not show the cross-ribbed surface from which *C. interrupta* took its name. The second was founded on distorted specimens of *Spirifera disjuncta*; and the so-called graptolites were lines of an asbestiform mineral following broken vein-like cavities, which had perhaps in some cases been occupied by encrinite-arms and stems, the joints of which, together with regular step-like displacements during the movements that modified the structure of the rock, produced the scalariform appearance of graptolites.

The Author had added greatly to our knowledge of the Devonian rocks by his discovery of fossils in the Morte Series, but the speaker thought that the rocks and fossils suggested a comparison with the Tintagel Beds rather than with the Silurian.

The Rev. G. F. Whidborne had had the privilege of following the Author's work in the field and collecting fossils with him, and he was convinced that the Author had not only found an abundant fauna in the 'unfossiliferous' Morte Slates, but had discovered the true bedding planes, and thereby proved the thickness of the deposits in North Devon to be much less than had been supposed. He had very carefully examined the fossils on the table, and was convinced that they did not present a Devonian facies. He had been unable to reconcile them with any Devonian fauna that he knew. Nor could he agree with Prof. Hughes that the large specimen of *Stricklandinia lirata* could by any possibility be a distorted *Spirifer Verneuili*. It differs from that form both in shape and minute ornament. The fragment of '*Cardiola interrupta*?' also seemed to be more like that fossil than anything else, though it was difficult to determine in its fragmentary condition. It certainly was not *Atrypa aspera*.

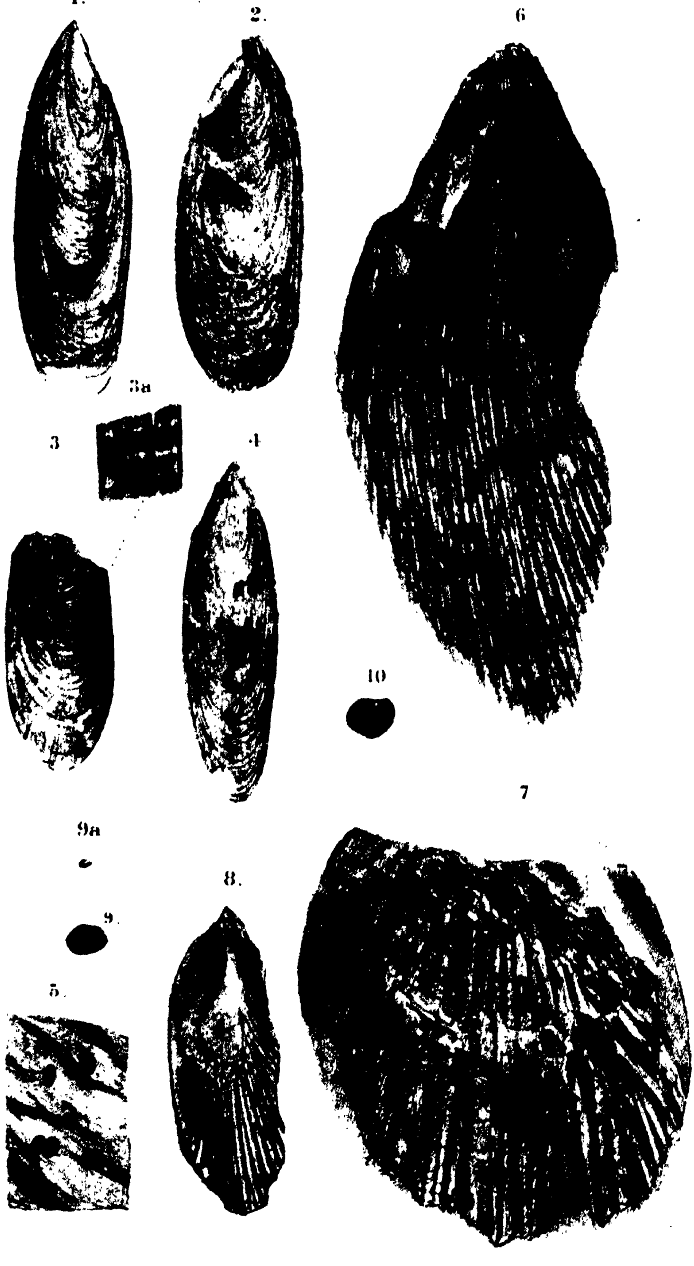
Mr. Marr said that the dip of the Ilfracombe Beds from the Morte Slates below the supposed thrust-plane was not evidence of the existence of a thrust-plane. But the serious evidence was that of the fossils. He maintained that none of the fossils exhibited were definitely proved to be Silurian. He could not see any indications of graptolitic structure in the specimens on the table. The greatest stress had been laid on the supposed *Stricklandinia lirata*. He wished that the gentleman who had identified that specimen had been present to say definitely that it was *Stricklandinia*. Considering the number of forms closely related to Silurian forms which had been found in American Devonian rocks (for example, *Pentamerus pseudogaleatus*), and the fact that in the richly fossiliferous deposits of Bohemia, Barrande's stages F, G, H, now shown by Kayser to be Devonian, were originally described as Silurian, he did not think that the distorted fossils displayed on the table could be taken as evidence for upsetting the received classification of the North Devon rocks. The Author was to be congratulated on the discovery of fossils in these supposed barren rocks, but the speaker, though having no objection to the reference of the Morte Slates to the Silurian, hoped that more evidence would be forthcoming in the

second part of the paper before they were definitely accepted as such.

Mr. H. B. Woodward remarked that the Devonian system had always suffered from being founded on zoological characters without clearly defined stratigraphical evidence. The Author's paper should be studied in conjunction with the excellent work of Dr. Hinde and Mr. Howard Fox on the radiolarian rocks, which were probably of the age of our Yoredale Beds. The precise equivalents of the lowermost Carboniferous in Devon were not established, and there had been no base to the Devonian system. For the sequence of Devonian faunas we had to take the divisions made in Germany; and as it was not clear that the base of the Carboniferous there was the same as that in this country, it might be questioned whether the continued use of the term 'Devonian' was justified. Agreeing that the subdivisions in Devon must be worked out by their fossils, he hoped that in so complicated a region the species would be identified solely from their zoological characters, while the best basis for such detailed work was an independent 6-inch survey of the area.

Mr. Hopkinson said that he had examined numerous specimens collected by the Author which bear a general resemblance to graptolites, and of which he exhibited drawings made under the microscope. Some of these might not be organic, others might be worm-tracks or encrinite-stems, or impressions of other organisms, but he felt certain that there were graptolites among them; they were, however, in so bad a state of preservation that it was impossible to identify them. He believed that most of the graptolites belonged to the genus *Monograptus*, and therefore were of Silurian age, but that Ordovician genera also occurred, showing that the rocks from which they had been obtained were of different horizons. Some of the branching forms were probably Cladophora, belonging to the genus *Dendrograptus*. He could not believe it possible that mineral matter could simulate, as suggested by Prof. Hughes, such forms as he then drew on the blackboard, one being typical of the *Monograptus Sedgwickii* group (having long curved denticles), and another resembling a scalariform impression of a *Climacograptus* (with transverse oval cell-apertures). He hoped that specimens would be obtained in a sufficiently perfect state of preservation to enable them to be specifically identified, dispelling all doubt as to their nature.

The Author said that he would reserve his reply until the second part of the paper is read, when evidence will be presented which will clear up many points referred to in the discussion. There can be no doubt that the Morte Slates, in their lithological characters and in their fossil contents, are entirely unlike the surrounding Devonian rocks.



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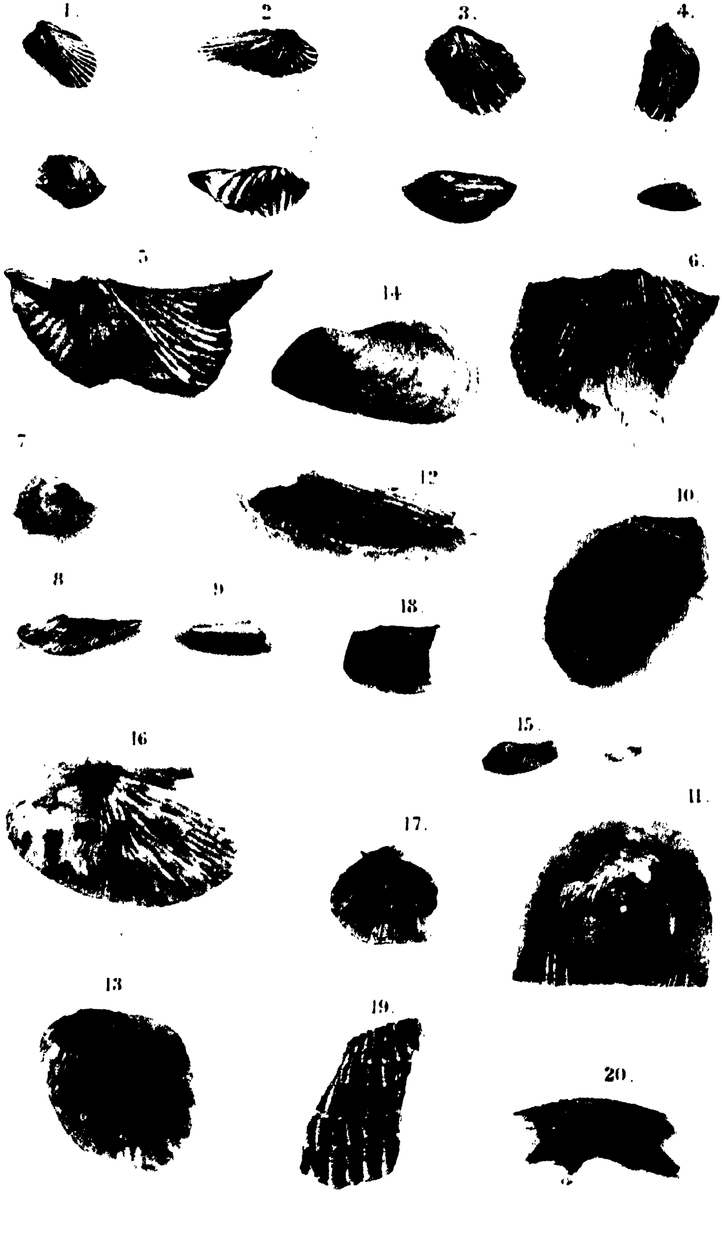

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14. *On the* LLANDOVERY *and* ASSOCIATED ROCKS *of* CONWAY (NORTH WALES).

By Miss G. L. ELLES and Miss E. M. R. WOOD, Bathurst Students, Newnham College, Cambridge. (Communicated by J. E. MARR, Esq., M.A., F.R.S., Sec. G.S.
Read January 8th, 1896.)

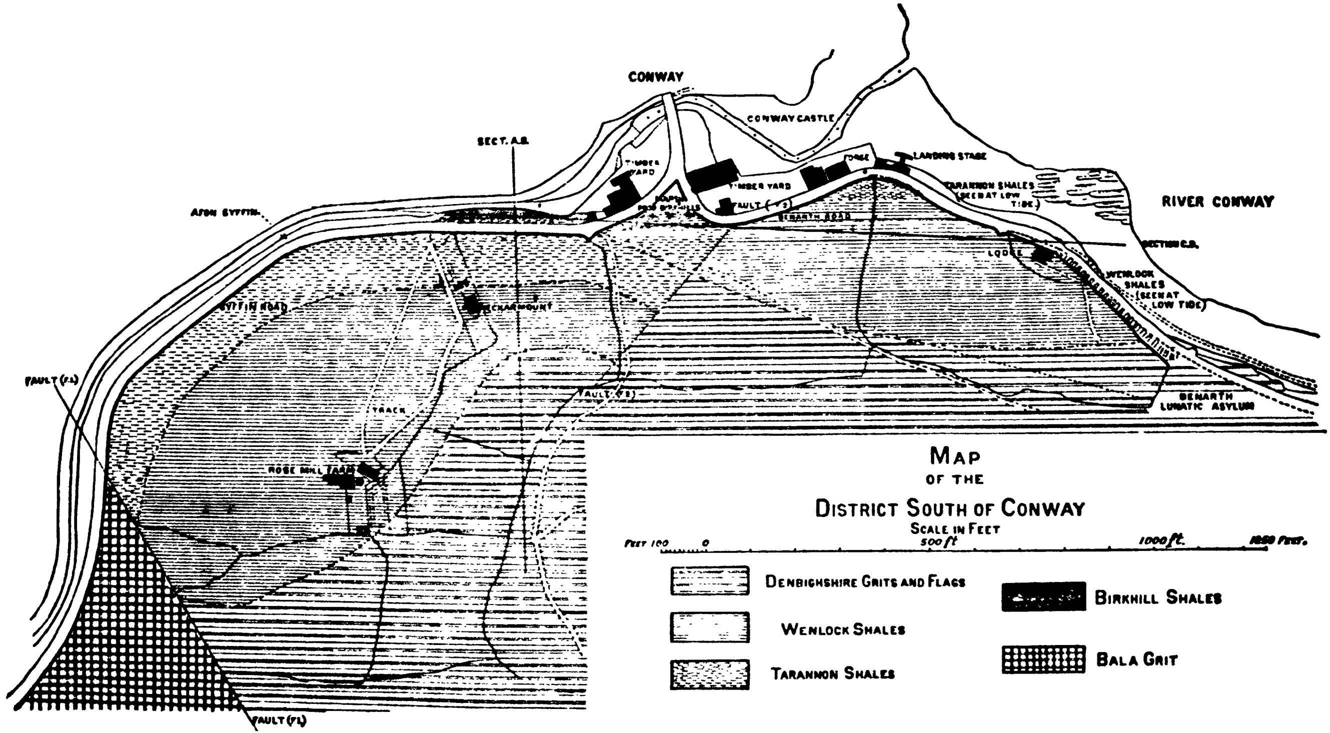
CONTENTS.

I. INTRODUCTION, AND DESCRIPTION OF AREA.

THE Geological Survey Map (Sheet 78 N.E.) of the district lying immediately south of the town of Conway reveals an outcrop of Tarannon Shales, which is curious as regards its relation to the associated formations, since the Tarannon Shales are represented as being both underlain and overlain by rocks of Wenlock age. This circumstance led us to examine this special area; and our attention having already been directed to the occurrence of graptolitic shales below the Tarannons in other parts of Wales, we thought it possible that they might also be present in the Conway district.

Our observations in that district have extended over a fairly wide region, including the greater part of the valley of the Afon Gyffin between Conway and Y-Ro; but the only area which we have mapped in anything like detail lies immediately south of the town of Conway itself, and occupies the hill opposite Conway Castle and the railway. This area is bounded on the east by the River Conway, and on the west by a fault ('boundary-fault,' as we term it in the following pages) which brings a calcareous grit of Bala age against Silurian beds.

The northern limit of the area is formed by the Afon Gyffin, a tributary stream of the River Conway, which it joins just below the Castle. The southern limit has been taken, for convenience, at the beginning of the dense woods belonging to Benarth Asylum. In other places higher up the valley, where we hoped to find a similar succession, the ground was low-lying and all rock-exposures were concealed beneath a tract of alluvium.


CONWAY
CONWAY CASTLE
RIVER CONWAY
LANDING STAGE
FORGE
TIMBER YARD
TIMBER YARD
TARANNON SHALES (SEEN AT LOW TIDE)
FAULT (F2)
BENARTH ROAD
SECT. A.B.
SECTION C.D.
LODGE
WENLOCK SHALES (SEEN AT LOW TIDE)
AFON GYFFIN
GYFFIN ROAD
BENARTH LUNATIC ASYLUM
TRACK
FAULT (F1)
FAULT (F2)
ROSE HILL FARM
FAULT (F1)
MAP
OF THE
DISTRICT SOUTH OF CONWAY
SCALE IN FEET
FEET 100
0
500 ft
1000 ft.
DENBIGHSHIRE GRITS AND FLAGS
WENLOCK SHALES
TARANNON SHALES
BIRKHILL SHALES
BALA GRIT

The geological structure of the area is fairly simple, though the beds are faulted and give indications of having been disturbed, the cleavage in many cases being in a direction at right angles to that of the plane of bedding. There is no great variation in the lithological characters of the beds; they are all of the general type known as 'greywacke,' and graduate locally from thick-bedded gritstones, through smooth flagstones, and thin-bedded hard grey shales down to fine-grained graptolitic mudstones. The only fossils with which we have to deal are graptolites, and their value for purposes of stratigraphical correlation is now too well known to need comment.

II. Literature.

The succession of rocks at Conway has received but little attention at the hands of geologists, and the literature is in consequence somewhat scanty. In the second edition of the Geological Survey Memoir on North Wales (1881) the succession at Conway is given as follows:—

Wenlock Shale. } Wenlock Beds.
Denbighshire Grit. }
Tarannon Shale.
(*Upper and Lower Llandovery Beds absent.*)
Caradoc or Bala Beds.

It is also suggested that the absence of Llandovery rocks between Conway and the country east of Bala Lake may possibly be due to the overlap of the Tarannon Shales, which are said to rest on Lower Silurian rocks at about the horizon of the Bala Limestone.

The Tarannon Shales form a narrow band at the base of the Denbighshire Grits extending from Conway to Llanbedr, about 5 miles to the south, being interrupted only by three small faults with a downthrow to the east.

On the hill immediately south of Conway the base of the grits, resting on a narrow band of Tarannon Shales, strikes towards Gyffin and, dipping east at an angle between 10° and 30°, passes south by Y-Ro to Caerhun, where the western boundary is lost in the alluvium of the River Conway. It is also stated that the grits pass up into the Wenlock Shale, but no mention is made of the considerable thickness of Wenlock Shale which we have found below the lowest grit-band in this district.

Prof. Lapworth, in his classical work on the 'Distribution of the Rhabdophora' (Ann. & Mag. Nat. Hist. ser. 5, vols. v. & vi. 1880, pp. 45, etc.), records the occurrence of many graptolites in the Tarannon Shales of Conway. On palæontological grounds he concludes that the Tarannon Shales of Conway correspond to the lowest portion of the Gala Group of Southern Scotland, that is, with the zone of *Monograptus exiguus*.

Our work necessitates a modification of the views of the earlier Surveyors, though we are in complete agreement with Prof. Lapworth's suggestion as to the horizon of the Tarannon Shales of this district.

III. General Sequence.

In this area we believe that we have a succession of graptolitic mudstones representing beds of Llandovery, Tarannon, and Wenlock ages, and we hope to show that the omission of Llandovery Beds in the Conway succession of the earlier surveyors was erroneous. We consider that the general sequence in descending order is as follows:—

5. Denbighshire Grits and Flags.
4. Wenlock Shales.
3. Tarannon Shales.
2. Upper Llandovery Beds.
1. Bala Beds.

The junction between the Bala and Llandovery rocks is nowhere visible. The former do not come to the surface south of the Afon Gyffin, but at the time of our first visit drainage-operations were in progress along the road passing the timber-yard on the way to Benarth, and at a few feet below the level of the road black graptolitic shales containing *Diplograptus foliaceus* (Murch.) and *Climacograptus bicornis* (Hall) were seen, apparently *in situ*, underlying the Tarannon Shales. If this be really the case, the Lower Tarannon rests unconformably on rocks of Bala Limestone age, and the succession is here different from that seen on the other side of the fault (F. 2 in map, p. 274), where Llandovery rocks occur, but it is unlikely that the Birkhill Shales have been overlapped in this short distance.

Since there is no junction visible between the Bala and Llandovery rocks, we are unable to determine definitely whether the Lower Llandovery rocks are absent or not in the district.

Note on the Bala Rocks of the Conway District.—On the other side of the River Conway, in a quarry of Bala rocks on the hill above Deganway, we have found remains of several large trilobites. Many seem referable to the species *Phacops appendiculatus* (Salt.) (=*P. eucentra*, Ang.?). This would tend to show that we have here representatives of the Ashgill Shale fauna of the Lake District. If this be the case, there exists in this part of North Wales a higher series of Ordovician rocks than has hitherto been supposed, and hence the break between Ordovician and Silurian rocks is less than was formerly believed to be the case.

The Upper Llandovery rocks pass up conformably into the Tarannons; but on palæontological grounds we believe that the latter are overlapped by the Wenlock Shales, and that the highest beds —that is, the zone of *Cyrtograptus Grayæ* (Lapw.)—are not present here.

The best section of the Wenlock Shales is to be seen on the shore below Benarth, and here we approximately determined the upper limit of these beds, on lithological grounds, at a point where the beds become more flaggy in character and contain bands of grit.

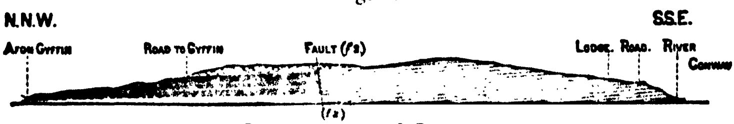
The exposures on the side of the hill were not sufficiently good to enable us to determine the upward limit with certainty.

There are two main faults in this district: one (F. 1), as has been mentioned above, forms our boundary-line to the W. and strikes 10° W. of N.; while a second one (F. 2), striking 30° S. of W. and

Fig. 1.

SECTION THROUGH A.B

Fig. 2.



SECTION THROUGH C.D.

with a downthrow to the E., brings the Upper Llandovery and Tarannon beds against the Wenlock Shales. We believe that the occurrence of Upper Llandovery Beds is dependent in a great measure on this second fault.

IV. Detailed Description of the Beds.

1. The Llandovery Rocks.

Rocks which are undoubtedly of Llandovery age occur on the right bank of the Afon Gyffin, from opposite Nockarmount House to the timber-yard buildings. Farther W. they are concealed beneath the alluvium of the river. They strike 10° N. of W., and dip 10° W. of S. at an angle of about 55°. Continuing on this strike, they are again seen in vertical section in the high bank opposite the fork formed by the junction of the Benarth and Gyffin roads; here they occur slightly below the level of the road, and probably occupy the whole of the marshy ground lying between the road and the bank.

(a) *Stream-section.*—The beds seen in section near the stream are capable of the following subdivisions, in descending order:—

7. Hard grey bed.
6. Black shale-band, with *Rastrites maximus.*
5. Grey flagstones.
4. Black shale-band, with graptolites.
3. Grey flagstones.
2. Black shale-band, with graptolites.
1. Very tough flagstones.

1. *Tough Grey Flagstones.*—Little need be said of the unfossiliferous beds forming the base of the section. They consist of tough grey flagstones, and are well exhibited in the bed of the

stream. They call to mind strongly the so-called Barren Mudstones of Moffat (Lapworth, Quart. Journ. Geol. Soc. vol. xxxiv. 1878, p. 240) and other areas. They are about 4 feet thick, but their base is not visible.

2. *Black Shale-band.*—This band is composed of typical black mudstones; it is only a few inches thick, and is much weathered, so that large blocks are not obtainable. We identified the following graptolites:—

us (Barr.).	*gregarius*, Lapw. C.
Hisingeri, var. *nudus* (Lapw.).	*Diplograptus tamariscus* (Nich.). C.
—— *Hisingeri*, var. *jaculum* (Lapw.).	*Climacograptus normalis* (Lapw.).

(C=very common. c=common. R=rare.)

3. *Grey Flags.*—The black fossiliferous band No. 2 is separated from the band No. 4 by a foot of grey flagstones, very similar in character to those found at the base of the section.

4. *Black Shale-band.*—Very similar to band No. 2, but fossils are rather more abundant. This band is also of inconsiderable thickness. We have found in it the following fossils:—

Monograptus concinnus (Lapw.).	*us sinuatus* (Nich.). C.
—— *Hisingeri*, var. *nudus*, Lapw.	*Hughesii* (Nich.).
—— ——, var. *jaculum* (Lapw.).	*tamariscus* (Nich.). C.
—— *gregarius*? (Lapw.).	*ptus normalis* (Lapw.). C.
—— *lobiferus* (M'Coy).	

5. *Grey Flagstones.*—These differ in no particular from those already described.

6. *Black Shale-band.*—This, the uppermost black shale-band that occurs in the section, is by far the most important. It is exposed about 3 yards from the top of the bank, below the uppermost bed of grey flagstones. The bed weathers very deeply, and has a curious rough fracture which renders it easily recognizable. The band is richly fossiliferous, and has yielded the following graptolites:—

Rastrites maximus (Carr.). C.	*Monograptus lobiferus* (M'Coy).
—— *gemmatus* (Barr.).	—— *spinigerus* (Nich.).
—— *distans* (Lapw.).	—— *turriculatus* (Barr.). R.
Monograptus argutus (Lapw.).	*Petalograptus ovatus* (Barr.).
—— *Barrandii* (?) (Suess).	—— *palmeus* (Barr.).
—— *concinnus* (Lapw.).	*Diplograptus sinuatus* (Nich.). C.
—— *gregarius* (Lapw.). R.	—— *tamariscus* (Nich.). C.
—— *galaensis* (Lapw.). R.	—— *Hughesii* (Nich.). C.
—— *Hisingeri*, var. *nudus* (Lapw.).	*Climacograptus normalis* (Lapw.). c.
—— ——, var. *jaculum* (Lapw.). c.	

(b) *Marsh-section.*—The beds seen in section in the bank of the marsh are, as before mentioned, a continuation of those seen by the stream, and here, as before, they dip steadily in towards the hill. The marsh, which occupies the space between the road and the bank, lies about 3 feet below the level of the road, but the ground rises somewhat towards the bank. Were it not for this depression, no Llandovery Beds would be seen here, as the band with *Rastrites*

maximus is found almost at the level of the road, and the black band No. 4 is only just visible at the foot of the bank. This band disappears almost at once when traced east or west, and the zone of *Rastrites maximus* is also lost at the level of the road on either side of the depression.

The section is, however, very interesting as affording an opportunity of studying the passage from the Llandovery rocks into the Tarannon Shales. There occurs in this place a graptolitic band above the zone of *Rastrites maximus*. This must be, from its position, either a passage-zone or the lowest bed of the Tarannon Shales. From the character of the fauna presently to be described, we prefer to regard it as a true passage-bed.

The following is the section seen at this locality, the strata being enumerated in descending order:—

	Ft.	In.
9. Spotted grey flagstones to summit.		
8. Black graptolitic band (probably passage-zone)	0	6
7. Grey flagstones, with hard gritty band about 1 inch wide at base	1	8
6. Shale band; zone of *Rastrites maximus*	1	0
5. Grey flagstones, unfossiliferous	1	0
4. Black shale-band, just visible.		

(The beds are numbered to correspond with those of the stream-section.)

From the nature of the exposure of No. 4, we scarcely expected to find any fossils. We succeeded, however, in obtaining a few graptolites, but these were too fragmentary for specific determination.

Zone of R. maximus, *Band No.* 6.—This band is easily recognizable by its characteristic fracture and mode of weathering. It has yielded the following graptolites:—

Rastrites maximus (Carr.). C.
Monograptus concinnus (Lapw.).
—— *spinigerus* (Nich.)?
—— *Hisingeri*, var. *nudus*, Lapw. C.
—— ——, var. *jaculum* (Lapw.). C.
—— *cyphus* (Lapw.).
—— *galaensis* (Lapw.). R.
Monograptus gregarius (Lapw.). R.
—— *crassus* (Lapw.).
—— *involutus* (Lapw.)?
—— *turriculatus* (Barr.). R.
Petalograptus ovatus (Barr.).
—— *palmeus* (Barr.).
Diplograptus tamariscus (Nich.). C.
—— *Hughesii* (Nich.). C.

It will be observed that in this locality and in the stream-section the zone of *Rastrites maximus* is characterized by the abundance of *Diplograptus* belonging to the species *Hughesii* (Nich.), *tamariscus* (Nich.), *ovatus* (Barr.), and *palmeus* (Barr.). The first two are by far the most numerous.

The upper limit of the Llandovery Beds appears to be well defined by the hard gritty band occurring at the base of No. 7.

8. *Fossiliferous Band.*—This differs somewhat in lithological characters from the lower graptolitic bands. It is not so black, nor is it so soft, being of a more gritty nature. It yielded the following fossils:—

Monograptus Hisingeri (Carr.).
* —— *crispus* (Lapw.).
* —— cf. *sartorius* (Tullb.).
cf. *speciosus* (Tullb.).
* —— *runcinatus* (Lapw.).
* *Monograptus pandus* (Lapw.).
—— *lobiferus* (M'Coy).
* —— cf. *nodifer* (Tullb.).
Diplograptus Hughesii (Nich.).
Climacograptus normalis (Lapw.).

It is this fauna which leads us to believe that the zone is a passage-zone, as the fossils marked with an asterisk are characteristic Tarannon forms, while the other species are common in the Llandovery Beds.

2. The Tarannon Shales.

(a) *Marsh-section.*—Unfortunately the lowest beds of the Tarannon Shales in this district are not very fossiliferous—at least in places which are accessible, for much of the section is obscured by buildings and lumber from the adjoining timber-yard.

At the corner of the road, however, we succeeded in obtaining two slabs on which were seen a number of badly preserved Monograptids. Many of these were too obscure for identification, but we have determined *M. pandus* (Lapw.), *M. Hisingeri*, var. *nudus* (Lapw.), *Cyrtograptus Lapworthi* (Tullb.), and *C.* (?)*spiralis* (Gein.). These beds were almost immediately faulted out against the Wenlock Shales.

(b) *Section opposite the Forge.*—The section of Tarannon Shales seen opposite the forge is by far the best in the district, and contains a rich graptolitic fauna. It was from these beds that Prof. Lapworth obtained the fossils recorded by him in his 'Distribution of the Rhabdophora' (Ann. & Mag. Nat. Hist. 1880, ser. 5, vols. v. & vi.). The strike of the beds does not appear to have been affected by the fault, and they dip 10° W. of S. at a fairly constant angle of about 55°.

The beds consist of alternations of hard grey unfossiliferous flagstones, with softer black shale-bands containing graptolites. They are quite different in character from the Llandovery rocks, and are not so fissile.

The following is the complete section seen; the lowest beds occur exactly at the corner by the forge, while higher beds come on along the road in either direction:—

	Ft.	In.
13. Soil and loose shale	4	0
12. Bands of hard grey flags, with softer seams. Unfossiliferous	2	6
11. Black shale-band, with graptolites. Very ferruginous and deeply weathered	1	6
10. Grey flagstones	0	9
9. Black shale-band, with graptolites. Very soft, and stained yellow	1	0
8. Grey flagstones	0	9
7. Soft black graptolitic shale	0	6
6. Grey flags, with narrow band of hard yellow grit: all very ferruginous	0	5
5. Soft black shale, with graptolites	0	9
4. Unfossiliferous grey flags	0	7
3. Black shale, with graptolites	0	9¼
2. Grey flags	1	0
1. Grey, sandy, graptolitic band; iron-stained above.		

(Base not seen.)

Band No. 1.—Lithologically this band differs from any of the other graptolite-bearing bands seen in this section. It may be roughly separated into two divisions :—

(*a*) Lower. Sandy grey bed.
(*b*) Upper. Flaggy bed, stained bright red.

In the lower of these two divisions the graptolites are very numerous but fragmentary, and for the most part very badly preserved ; those in the upper division are more easily determinable. We obtained the following fossils :—

Monograptus pandus (Lapw.). C.
—— *runcinatus*, var. (Lapw.).
—— *exiguus* (Nich.). C.
—— *nodifer* (Tullb.).
—— *Hisingeri*, var. *nudus* (Lapw.).
—— ——, var. *jaculum* (Lapw.).
—— *broughtonensis* (Nich.).
Monograptus speciosus (Tullb.).
—— *crispus* (Lapw.).
—— *turriculatus* (Barr.).
—— *Becki* (Barr.)?
—— ? *urceolus* (Richter).
Petalograptus palmeus (Barr.).
Diplograptus tamariscus (Nich.).

The unfossiliferous flagstones are very similar throughout ; they consist of pale grey flaggy beds, occasionally somewhat gritty, and are often very hard. Some of the upper beds are speckled.

Band No. 3.—This soft mudstone-band has yielded the following forms :—

Monograptus pandus (Lapw.).
—— *runcinatus*, var. (Lapw.).
—— *exiguus* (Nich.). C.
—— *turriculatus* (Barr.). C.
—— cf. *cygneus* (Tornq.).
Monograptus ? *urceolus* (Richter).
—— cf. *flexuosus* (Tullb.).
—— *capillaceus* (Tullb.).
Petalograptus palmeus (Barr.).

Band No. 5.—From this band we have identified

Monograptus turriculatus (Barr.).
—— *pandus* (Lapw.).
—— *runcinatus*, var. (Lapw.).
—— *Hisingeri*, var. *nudus* (Lapw.).
—— *exiguus* (Nich.).
—— *crispus* ? (Lapw.).
Monograptus galaensis (Lapw.).
—— *Flemingii* (Salter).
—— ? *urceolus* (Richter).
—— *Proteus* (Barr.).
Petalograptus palmeus (Barr.).
—— *ovatus* (Barr.).

Band No. 7.—This contains

Monograptus turriculatus (Barr.). C.
—— *exiguus* (Nich.).
—— *Hisingeri*, var. *nudus* (Lapw.).
—— *pandus* (Lapw.).
Monograptus speciosus (Tullb.).
—— *retroflexus* ? (Tullb.).
Diplograptus tamariscus (Nich.).

Band No. 9.—This bed is peculiar, because of its being stained bright yellow ; it has yielded

Monograptus pandus (Lapw.).
—— *turriculatus* (Barr.).
—— *crispus* (Lapw.).
—— *exiguus* (Nich.).
—— *priodon* (Bronn).
—— *Hisingeri*, var. *nudus* ? (Lapw.).
Monograptus Hisingeri, var. *jaculum* (Lapw.).
Petalograptus ovatus (Barr. ?). C.
—— *palmeus* (Barr.). C.
Retiolites Geinitzianus (Barr.).

Band No. 11. This band consists of black flaggy mudstones, deeply weathered and often iron-stained. It breaks characteristically into

lath-shaped fragments with a splintery fracture. We have obtained from it the following:—

Monograptus pandus (Lapw.). C.
—— *runcinatus*, var. (Lapw.). C.
—— *exiguus* (Nich.). C.
—— *attenuatus* (Hopk.).
—— *crispus* (Lapw.).
—— *broughtonensis* (Nich.).
—— *turriculatus* (Barr.). C.
—— *riccartonensis* (Lapw.).
——, sp. nov.
—— *Hisingeri*, var. *nudus* (Lapw.).
—— ——, var. *jaculum* (Lapw.).
—— *galaensis* (Lapw.).

Monograptus speciosus (Tullb.).
—— cf. *cygneus* (Törnq.).
—— *priodon* (Bronn).
—— *concinnus* (?), Lapw.
—— ? *urceolus* (Richter).
Petalograptus ovatus (Barr.).
—— *palmeus* (Barr.). C.
Diplograptus tamariscus (Nich.).
—— *Hughesii* (Nich.).
Retiolites Geinitzianus (Barr.).
—— *obesus* (Lapw.).

Strictly speaking, this band might be divided as follows:—

(*a*) Graptolitic Shale.
(*b*) Unfossiliferous Flags.
(*c*) Graptolitic Shale.

But (*b*) is of such insignificant thickness that for practical purposes it seems better to group the three as one bed.

It will be evident from these lists that several species of graptolites are common to all the bands: for example, *Monograptus exiguus* (Nich.) and *M. turriculatus* (Barr.) range throughout, and have been found on the same slab; *M. pandus*, Lapw., and *M. runcinatus* var., Lapw., are also commonly associated with these.

(c) *Shore-section.*—The only other place where we found a workable section was that seen at low tide on the shore between the timber-yard and the lodge belonging to the Benarth Lunatic Asylum. The section commenced just at the old landing-stage.

The dip and strike remain constant as before, but, owing to the fact that beds are denuded along their dip, they are exposed somewhat farther to the south than is the case in the road. Unfortunately, where we hoped to find the highest beds the section was obscured by sand and shingle, and the rocks next visible were certainly of Wenlock age, since they contained *Monograptus priodon* (Bronn), *M. vomerinus* (Nich.), etc.

We believe that there is a continuous outcrop of Tarannon Shales from the fault (F. 2) to F. 1, the boundary-fault; but there are no good exposures, as the ground is chiefly a grassy slope. The presence of these beds was therefore in most cases inferred by the disappearance of the feature invariably formed by the Wenlock Shales.

3. The Wenlock Shales.

A considerable thickness of Wenlock Shale underlies the lowest band of Denbighshire Grit in this district. The outcrop assumes a curious form to the west, owing to the presence of the fault (F. 1) and to the configuration of the ground.

Lithologically, the beds differ markedly from the underlying

Tarannon Shales; they are generally harder, of a lighter, often speckled colour, and in places very shivery. The fossils are fairly well preserved, but, owing to the direction of the cleavage, are often difficult to obtain. The beds change their strike somewhat as they approach the faults, being in each case bent up towards them; this is especially well marked in the case of the fault which forms the boundary of the Silurian rocks to the west. We were fortunate in having several workable exposures on the hillside, and these we will proceed to describe in some detail.

(i.) Sections West of Fault (F. 2).

(α) *Section S.W. of Rose Mill Farm.*—The sections exposed near Rose Mill Farm are of small extent. They are chiefly interesting as showing the alteration in the strike of the beds as these approach the fault. Here the strike is 20° N. of W., while as a general rule it is 10° N. of W. The fossils here are for the most part but poorly preserved, but we have identified *Monograptus personatus*, Tullb., *M. vomerinus*, Nich., *M. broughtonensis* (Nich.), and *Cyrtograptus Murchisoni*, Carr. At Rose Mill Farm itself the shales are very shivery, and from the nature of the rock no fossils were obtainable. Here and south of the farm the strike is 15° N. of W.

(β) *Neckarmount.*—An exceedingly good section is exposed along the rough cart-track which leads up from the road, past Neckarmount House, to the farm.

The beds appear to come on about 160 yards above Gyffin Road; they dip steadily into the hill to the S.S.W. at a high angle of about 50°, and maintain a constant strike 10° N. of W. The shales do not appear to be equally fossiliferous throughout. In some bands graptolites are abundant, while others appear to be quite unfossiliferous. The fossiliferous bands yielded *Monograptus priodon*, Bronn, *M. vomerinus*, Nich., *M. personatus*, Tullb., *M. flexuosus*, Tullb., *M. Hisingeri*, var. *rigidus* (?), Lapw., and *Cyrtograptus* sp.

East of Neckarmount the harder unfossiliferous bands are exposed, at the top of a sudden rise of ground. Here the direction of strike changes to 20° N. of W. This is evidently due to the presence of the fault (F. 2), which is at this place in close proximity.

(ii.) Sections East of Fault (F. 2).

(α) *Road-section.*—As mentioned above, the Wenlock Shales are faulted against the Tarannon Shales to the west. Unfortunately the beds here are so deeply weathered that fossils are exceedingly rare, but the change in the character of the rocks, in addition to palæontological evidence, enables us to affirm with some certainty that the beds are of Wenlock age. The only graptolites obtainable were *Monograptus vomerinus*, Nich. (1 specimen), *M. flexuosus*, Tullb. (1 specimen), and *Cyrtograptus*? (1 specimen).

(β) *Hillside-sections.*—On the hillside, immediately above, the exposures yielded several graptolites, belonging, however, to but few species: *Monograptus priodon*, Bronn, *M. personatus*, Tullb., *M. vomerinus*, Nich., and *M. flexuosus*, Tullb.

This exposure was traceable, with interruptions, round the hill to above the lodge leading to Benarth Asylum.

(γ) *Shore-section.*—The section of Wenlock Shales exposed on the shore at low tide is very complete. These beds first appear just below the end of the lodge garden, and continue for some distance along the shore. The lower beds are very shivery in character, but as higher beds are reached they become more compact and finally pass up into the hard flagstones with intercalated grit-bands belonging to the series of Denbighshire Grits and Flags. The following fossils were obtained:—*Monograptus priodon*, Bronn; *M. personatus*, Tullb.; *M. vomerinus*, Nich.

4. The Denbighshire Grits and Flags.

The boundary-line between the Wenlock Shales and the Denbighshire Grits and Flags east of the fault (F. 2) is approximately correct; but between this fault and the western limit exposures are rare, and the boundary cannot be fixed with any accuracy. Quite near the western fault exposures are more abundant, and the alteration of strike near the line of disturbance is perfectly evident.

V. Correlation with other Areas.

1. The Llandovery Rocks.

The general character of the graptolites found on the bank of the stream and in the road-section shows that the beds are nearly related to the Upper Birkhill Shales of Southern Scotland, and also to similar beds occurring in the Lake District and elsewhere.

We do not think that it is possible to trace at Conway all the minuter subdivisions recognized at Moffat, but certainly our highest band (No. 6 of the stream-section) corresponds with the uppermost zone of the Birkhill Shales, namely with the zone of *Rastrites maximus*. The bands below (Nos. 2 and 4) may subsequently be found to be the equivalents of lower zones, but in the present state of our knowledge it is wisest to say only that the beds contain an Upper Birkhill fauna. The following table shows the species common to the beds in various areas:—

Conway.	Scotland.		Lake District.		Central Wales.
Llandovery Beds.	Zone of *Rastrites maximus*.	Upper Birkhill.	Middle Skelgill.	Upper Skelgill.	
* *Rastrites maximus* (Carr.)........	*	*	......	*	*
—— *gemmatus* (Barr.)	......	......	*	......	......
* —— *distans* (Lapw.).....	*	*	......	......	......
—— *peregrinus* (Barr.)...........	*	*	*	......	*
* *Monograptus argutus* (Lapw.) ...	......	*	*	......	......
—— *Barrandii* (Tullb.)	......	......	......	......	......
* —— *concinnus* (Lapw.)....	*	*	*	......	......
* —— *cyphus* (Lapw.)...............	......	*	*	......	......
—— *crassus* (Lapw.)...............	*	*	......	*	......
* —— *gregarius* (Lapw.)...........	*	*	*	*	......
—— *galaensis* (Lapw.)	*	*	......	......	......
—— *Hisingeri*, var. *nudus* (Lapw.)	......	......	......	......	......
—— *involutus* (Lapw.)	*	*	*	*	*
* —— *lobiferus* (M'Coy)	*	*	*	......	*
—— *runcinatus* (Lapw.)	......	*	......	*	*
* —— *spinigerus* (Nich.)	*	*	......	......	......
* —— *turriculatus* (Barr.)	*	*	......	*	*
Petalograptus ovatus (Barr.). ...	*	*	......	......	......
* *Diplograptus Hughesii* (Nich.) ...	*	*	*	*	......
* —— *palmeus* (Barr.)...............	*	*	......	*	......
—— *sinuatus* (Nich.)...............	*	*	*	*	......
* —— *tamariscus* (Nich.)..........	*	*	*	*	......
* *Climacograptus normalis* (Lapw.)	*	*	*	*	......

As shown by this table, the correspondence between the fauna of the Conway beds and that of the Upper Birkhill Shales is very close. As the study of our fossil lists will show, the species are by no means evenly distributed throughout the three bands.

Some forms, which are very rare in the zone of *Rastrites maximus*, are far more characteristic of the Tarannon Shales; such, for instance, as *Monograptus turriculatus*, *M. galaensis*, *M. pandus*, and *M. Barrandii*. Others occur more abundantly in the lower bands (2 and 4), and may indicate the presence of lower zones. *Monograptus gregarius* is fairly common in band No. 2, but we have succeeded in obtaining only one specimen from the zone of *Rastrites*

Rastrites peregrinus was found only in the lowest band (No. 2). The poverty of the fauna from this lowest band was no doubt in part due to the very small extent of the exposure; had we been enabled to work it better, we probably should have found it possible to definitely determine its age.

2. The Tarannon Shales.

The correlation of the lowest fossiliferous band of the Tarannon Group is a matter of some difficulty. We did not succeed in finding

Monograptus turriculatus; but the fauna, on the whole, shows affinities with the underlying and overlying beds, and we therefore consider that it is of the nature of a passage-bed. We do not know its exact equivalent in other areas.

The main mass of the Tarannon Shales may be correlated with the lower of the two groups into which Prof. Lapworth (Ann. & Mag. Nat. Hist. ser. 5, vols. v. & vi. 1880) has divided the Gala rocks of the Southern Uplands of Scotland—that is, the zone of

It does not seem possible to recognize here the two sub-zones defined by Messrs. Marr and Nicholson (Quart. Journ. Geol. Soc. vol. xliv. 1888, p. 654) in the Lake District. There they found (1) zone of *Monograptus turriculatus* (Barr.) and (2) zone of *M. crispus* (Lapw.). In our beds *M. turriculatus* and *M. exiguus* range together throughout, but it is noticeable that the genus *Retiolites* is confined to the uppermost members of the series.

The following table shows the relation of the Tarannon Shales of Conway to beds of similar age in the Lake District and Southern Scotland:—

Conway.	Lake District.	South Scotland.
Tarannon Shales.	Browgill Shales.	Lower Gala.
* *Monograptus Becki* (Barr.)	......	*
—— *broughtonensis* (Nich.)	*	......
* —— *crispus* (Lapw.)	*	*
—— *concinnus* (Lapw.)...........	......	*
* —— *exiguus* (Nich.)	*	*
—— *Flemingii* (Salt.)	......	*
—— *galaensis* (Lapw.)	......	*
—— *Hisingeri*, var. *nudus* (Lapw.)	*	*
—— *priodon* (Bronn)	......	*
* —— *pandus* (Lapw.)...............	*	......
—— *runcinatus*, var. (Lapw.) ...	......	*
* *Cyrtograptus spiralis* (Gein.) ...	*	......
Petalograptus ovatus (His.)	......	*
—— *palmeus* (Barr.)...............	*	*
Diplograptus tamariscus (Nich.)	......	*
* *Retiolites Geinitzianus* (Barr.)...	*	......
* —— *obesus* (Lapw.)	*	*

It is interesting to note that several of the graptolites found in the Tarannon Shales of Conway seem to be identical with many Swedish forms of the same age.

3. The Wenlock Shales.

The correlation of these beds is matter of no difficulty; they seem to be the equivalents of the Pen-y-glog Slates of the Dee Valley

(Lake, Quart. Journ. Geol. Soc. vol. li. 1895, p. 9), the Brathay Flags of the Lake District (Marr, Geol. Mag. 1892, p. 535), and the Riccarton Flags of Scotland.

CONWAY.	DEE VALLEY.	LAKE DISTRICT.	SCOTLAND.
Wenlock Shale.	Pen-y-glog Slates.	Brathay Flags.	Riccarton Beds.
Monograptus priodon (Bronn).	*	*	*
—— *vomerinus*, Nich.	*	*	*
—— *personatus* (Tullb.).........	*	*	...
Cyrtograptus Murchisoni (Carr.)	*	*	...

There also occurs at Conway *Monograptus flexuosus*, which is a Swedish form of Wenlock Shale age.

4. The Denbighshire Grits and Flags.

The Denbighshire Grits and Flags, from their position above the Wenlock Shales, are in all probability the equivalents of the beds overlying the Pen-y-glog Slates in the Dee Valley, which Mr. Lake has shown (*op. cit.*) to be of Lower Ludlow age.

Approximate Correlation of Beds.

CONWAY.	CENTRAL WALES AND WESTERN ENGLAND.	LAKE DISTRICT.	SCOTLAND.
Denbighshire Grits and Flags.	Denbighshire Grits and Flags. { Nant-Glyn Flags, Moel-Ferna Slates, and Pen-y-glog Grit.	Coldwell Beds.	
Wenlock Shales.	Wenlock Shales (Pen-y-glog Slate).	Brathay Flags.	Riccarton Flags.
(Upper beds absent.) Tarannon Shales.	1. Zone of *Retiolites Geinitzianus*, *C. Grayæ*. 2. Zone of *Monograptus turriculatus*, *M. exiguus*, etc.	Upper Browgill Beds. Lower Browgill Beds.	Upper Gala Beds. Lower Gala Beds.
Upper Llandovery Beds.	Llandovery Beds of Cardigan and Dee Valley.	Upper Skelgill Shales.	Upper Birkhill Shales.

VI. General Conclusions.

From the facts brought forward in the present paper it is evident that rocks of Llandovery age do occur in North Wales, and hence that the stratigraphical break in that region between the Silurian and Ordovician rocks is, at any rate, far less actually than has hitherto been supposed.

The type of Llandovery rocks developed at Conway is more closely related to that of Southern Scotland and Northern England than to that of the typical Welsh Borderland area, and it is interesting to observe that here, at any rate, deep-water conditions prevailed from Upper Llandovery to Wenlock times.

With regard to the Tarannon Shales, Wenlock Shales, and Denbighshire Grits and Flags, they differ in no essential respect from those found in the Dee Valley, which have been recently shown (Lake, Quart. Journ. Geol. Soc. vol. li. 1895, *op. cit.*) to be the normal type, and therefore require no further comment.

Our best thanks are due to Mr. J. E. Marr, F.R.S., and Prof. Charles Lapworth, F.R.S., for much kind help and assistance in our work.

Discussion.

The President said that the Authors of this paper had made an exhaustive survey of a limited area, collecting the fossils and correlating with care the graptolites from each horizon. Such work deserved the Society's praise, as following the example of Prof. Lapworth and other careful workers. Such accurate field-work, coupled with careful palæontological results, was of the greatest value.

Dr. Hicks said that he had listened with much interest to the paper, and he hoped the Authors would continue their researches into other areas in North Wales, for it is highly important that the fossil-zones in the beds forming the base of the Silurian in that area should be clearly defined. He had not examined the sections referred to by the Authors, but some years ago he found that the sandstones on the eastern side of the Conway valley (towards Llanrwst) contained *Nematophycus* and other fossils characteristic of the Pen-y-glog Beds near Corwen. He would have liked to hear whether the Authors considered that the deep-water beds of Upper Llandovery age at Conway rested directly on the Bala Beds, and whether there was an entire absence of the beds near Bala classed by Mr. Ruddy as Lower Llandovery.

Mr. W. W. Watts congratulated the Authors on a most admirable piece of work. He pointed out how the Upper Llandovery rocks had been gradually recognized and extended. There was no gap between those of Shropshire and of Conway, for the rocks had been recognized on the Breiddens, near Meifod in Montgomeryshire, and in the Berwyns. There appeared to be no evidence of conformity between the Ordovician and Silurian rocks in the Conway district, in spite of the fact that somewhat deep-sea beds had been found there. He hoped that the Authors would recognize the *Monograptus colonus*- and *M. leintwardinensis*-beds in the Denbighshire Grit.

15. EVIDENCES *of* GLACIAL ACTION *in* AUSTRALIA *in* PERMO-CARBONIFEROUS TIME. By T. W. EDGEWORTH DAVID, Esq., B.A., F.G.S., Professor of Geology in the University of Sydney. (Read February 5th, 1896.)

[PLATE XII.]

CONTENTS.

THE subject of which this paper treats has already been traversed by the author in his Presidential address to the Geological Section of the Australasian Association for the Advancement of Science, at its meeting at Brisbane in January 1895.

The author hopes, however, that the presentation to this Society of a summary of these previous records,—with the addition of his subsequent field-work in 1895,—will be justified by the opportunity now given of a discussion which will be of immense benefit in furthering an important and interesting branch of geological investigation.

The personal observations recorded in this paper are the result of 13 years', more or less constant, field-work in Australia.

I. WORK DONE BY PREVIOUS OBSERVERS.

The first actual record of evidence of ice-action in Australia is probably that made by Dr. A. R. C. Selwyn in 1859.[1]

The statement is as follows:—'At one point in the bed of the Inman I observed a smooth, striated, and grooved rock-surface presenting every indication of glacial action. The bank of the creek showed a section of clay and coarse gravel, or drift, composed of fragments of all sizes irregularly interbedded through the clay. The direction of the grooves and scratches is E. and W. in parallel lines; and though they follow the course of the stream, I do not think they could have been produced by the action of water forcing pebbles and boulders detached from the drift along the bed of the stream. This is the first and only instance of the kind I have met with in Australia, and it at once attracted my attention, strongly reminding me of the similar markings I had so frequently observed in the mountain-valleys of North Wales.'

These very important observations appear to have been lost sight

[1] 'Geological Notes of a Journey in South Australia from Cape Jarvis to Mount Serle,' by A. R. C. Selwyn, Parliamentary Paper, no. 20, Adelaide, 1859, p. 4.

of for about 35 years, and Australian geologists have not yet had an opportunity of confirming them; but the subsequent discoveries in this neighbourhood by Prof. Ralph Tate, of Adelaide University, leave no doubt as to their accuracy.

In 1860 the Rev. W. B. Clarke[1] recorded the existence of a few 'blocs perchés' in the Australian Alps.

In 1866 Sir Richard Daintree[2] recorded evidences of ice-action in the districts of Bacchus Marsh and Ballan, in Victoria, in these words:—'Here [on the Lerderberg River, Bacchus Marsh, Victoria] I have found a few pebbles grooved in the manner I have read of as caused by glacial action.'

This observation has been confirmed by several geological workers, including the present author; and glaciated boulders from near this locality were exhibited at the meeting when this paper was read.

In 1877 Prof. Ralph Tate[3] discovered a glaciated rock-pavement capped by glacial beds at Hallett's Cove, near Adelaide, and on May 7th of that year he recorded his discovery in a course of public lectures. The glaciated rock-pavement is described as being of Archæan age and as forming the summit of the sea-cliffs for a distance of about a mile in a N. and S. direction, with a width of a few yards, and as terminating inland against a low mural escarpment of Miocene limestone. Recent observations by Mr. A. W. Howchin, Prof. Ralph Tate, and the author, show that this pavement extends for at least ¼ mile under the Miocene limestone. The glacial beds which intervene between the pavement and the Miocene limestone are stated to contain blocks of rock derived from an area about 35 miles to the south. The pavement is described as being smoothed and striated in a north-and-south direction, and as showing evidence that the ice which caused the striation came from the south.

In 1879 Mr. R. L. Jack[4] recorded his discovery of blocks of granite, slate, etc., contemporaneously embedded in strata of Permo-Carboniferous age, in the Bowen River Coalfield, Queensland. The presence of these blocks is attributed by Mr. Jack to the action of floating ice.

In 1879 the late Mr. C. S. Wilkinson[5] recorded what he considered to be evidence of glacial action in the Triassic Hawkesbury Series of New South Wales. This evidence consists of disrupted masses of clay-shale, of all sizes up to 20 feet in diameter, embedded in sandstone.

[1] 'Researches in the Southern Goldfields of New South Wales,' Sydney, 1860, p. 225.

[2] Geological Survey of Victoria. 'Report on the Geology of the District of Ballan, including Remarks on the Age and Origin of Gold, etc.' By Richard Daintree. Melbourne, 1866.

[3] See Rep. Austr. Assoc. Adv. Science, vol. i. pp. 231-232, Sydney, 1887; *ibid.* vol. v. p. 31, Adelaide, 1893; also Trans. Roy. Soc. S. Austr. vol. ii. 1879, p. lxiv.

[4] 'Report on the Bowen River Coalfield,' by Robert L. Jack, p. 7, par. 39, Brisbane, 1879.

[5] Journ. Roy. Soc. N. S. Wales, vol. xiii. 1879, 'Notes on the Occurrence of remarkable Boulders in the Hawkesbury Rocks,' pp. 105-107.

In 1884 Mr. R. M. Johnston[1] of Tasmania described the occurrence of erratics, some over a ton in weight, in the Permo-Carboniferous rocks of Maria Island, Tasmania.

In 1885 Mr. R. D. Oldham[2] visited Branxton in New South Wales (where Mr. C. S. Wilkinson had the previous year discovered some large erratics), and found one small boulder which he described as being unmistakably striated and polished by ice. This deposit is of Permo-Carboniferous age, and probably homotaxial with the erratic-beds of the Bowen River Coalfield, Queensland, and those of similar age in Tasmania. Mr. Oldham correlates the Branxton beds with those of Bacchus Marsh in Victoria, and suggests that they may be the equivalents of the Talchirs of India. He also suggests that during the deposition of these beds 'there was a widespread glacial epoch corresponding to that which is known to have occurred in post-Tertiary time.'

In 1886 Mr. R. M. Johnston[3] recorded further evidence of erratics in Permo-Carboniferous rocks at One Tree Point, Bruni Island, Tasmania. They are embedded in marine strata with which is associated *Gangamopteris spathulata*, M'Coy.

In 1887 the author[4] recorded the occurrence of numerous erratics in Permo-Carboniferous strata at Grasstree in New South Wales.

They are mostly rounded, seldom angular; none observed were distinctly glaciated, though many were faintly striated, possibly through earth-movements. About the same time the author observed, near Branxton, a block of granite nearly a ton in weight, embedded in the Permo-Carboniferous strata in such a position as to leave no other explanation possible than that it had been dropped from floating ice. (A photograph of this was exhibited at the meeting.)

In 1890 the late Dr. Feistmantel[5] correlated the Bacchus Marsh Beds of Victoria and the Upper and Lower Marine Beds of New South Wales with the Dwyka Conglomerates of Southern Africa, and with the Talchir Boulder-beds of India. The *Productus*-limestone which in the Salt Range caps the Talchir Boulder-beds afforded palæontological evidence for the above correlation.

Feistmantel summarizes the evidence as follows:—'This circumstance [the occurrence of ice-scratched boulders in the strata] would, of course, indicate a rather general change of climatic conditions over Australia, portions of Africa, India, etc. towards the close of the Carboniferous epoch. But I do not think that it was contemporaneous over that whole region, and it appears to me that it set in first in Eastern Australia (New South Wales), destroying

[1] Proc. Roy. Soc. Tasmania, 1884, p. lxv.

[2] Rec. Geol. Surv. India, vol. xix. pt. i. p. 44.

[3] Proc. Roy. Soc. Tasmania, 1886, pp. 23-24.

[4] 'Evidence of Glacial Action in the Carboniferous and Hawkesbury Series in N. S. Wales,' Quart. Journ. Geol. Soc. vol. xliii. pp. 190-196.

[5] 'The Geological and Palæontological Relations of the Coal- and Plant-bearing Beds of Palæozoic and Mesozoic Age in E. Australia and Tasmania,' Mem. Geol. Surv. N. S. W. Pal. No. 3, pp. 46, 47, 181.

the Carboniferous flora at an early date, while in Southern Africa we find still a Carboniferous or Coal-Measure flora of a higher stage, and only hereafter the change of climate appears to have taken place there. When the conditions of ice-action ceased, there appeared in Africa, India, Victoria, New South Wales, etc., a luxuriant flora of a peculiar character, which was, however, foreshadowed by a few forms in the Lower Coal Measures in New South Wales. In this period falls the deposition of the Karoo Formation in Africa, the Gondwána System in India, the Newcastle Beds, etc., in New South Wales, the Bacchus Marsh Beds in Victoria, and so on.'

In 1890 Mr. E. J. Dunn [1] published a very important paper on the glacial conglomerates of Victoria. He showed that they were widely distributed on either side of the Main Dividing Range of Victoria, Wild Duck Creek near Heathcote to the north, and Bacchus Marsh to the south, being the principal localities. He described the glacial conglomerates as consisting of fragments of rock up to 30 tons in weight, mostly well rounded, frequently polished, strongly striated, grooved and faceted, more rarely angular, embedded in a groundmass of a prevailing dark grey colour. The rocks constituting the boulders are stated to be for the most part foreign to the district. Mr. Dunn says (*op. cit.* p. 456), 'No other conclusion can be arrived at than that floating ice has been the agent by which the material has been brought into its present position .... Tasmania may have furnished some of them' [*i. e.* the erratics].

In 1891 Mr. G. B. Pritchard [2] recorded the occurrence of glaciated rock-surfaces at a spot to the north of the township of Curramulka, on the eastern side of Yorke Peninsula, South Australia. This evidence can be confidently correlated with that previously discovered by Prof. Ralph Tate at Hallett's Cove.

In 1892 Mr. E. J. Dunn [3] published another important and well-illustrated report relating specially to the glacial deposits of Wild Duck Creek. Mr. Dunn recorded therein his discovery of a strongly glaciated rock-surface near Wild Duck Creek, the striæ trending north and south. The altitude of the upper portion of the glacial conglomerate is stated to be about 700 feet above the sea.

In 1892 Messrs. Dunn and T. B. Moore [4] published evidence of a glacial conglomerate, 3000 feet above sea-level, near Zeehan in Tasmania. The included boulders were found to be beautifully striated. This formation should, in Mr. Dunn's opinion, be correlated with that of Bacchus Marsh.

In 1893 Mr. T. B. Moore [5] recorded the occurrence at Mount Tyndall of a glacial conglomerate, considered by him to be of

[1] Rep. Austr. Assoc. Adv. Science, vol. ii. pp. 452–456, Melbourne, 1890.

[2] Trans. Roy. Soc. South Australia, vol. xv. (1891–92) p. 182.

[3] 'Notes on the Glacial Conglomerate, Wild Duck Creek,' by E. J. Dunn, F.G.S.; Special Reports, Department of Mines, Victoria. Melbourne, 1892.

[4] Proc. Roy. Soc. Victoria, n. s. vol. vi. (1894) pp. 133–138, pl. viii.

[5] 'Discovery of Glaciation in the Vicinity of Mount Tyndall, in Tasmania,' by T. B. Moore, Proc. Roy. Soc. Tasmania, 1893, pp. 147–149.

the same geological age as that already referred to near Zeehan. Its altitude was estimated to be 3500 feet.

In 1893 Mr. A. Montgomery questioned the accuracy of Mr. T. B. Moore's determination of the geological age of the glacial conglomerate at Mount Tyndall as being Permo-Carboniferous, and suggested that it might be a re-distributed Permo-Carboniferous conglomerate glaciated perhaps in Tertiary time.

In 1893 Messrs. Graham Officer and L. Balfour[1] published an account, well illustrated, of the Bacchus Marsh conglomerates. They considered the glacial conglomerates referable to two distinct epochs, one belonging to Permo-Carboniferous, the other to Tertiary time. In a subsequent paper,[2] however, they withdrew their opinion as to the evidence in this neighbourhood of any Tertiary glaciation.

In September 1893 Messrs. G. Sweet and C. C. Brittlebank[3] published an important paper on the glacial deposits of the Bacchus Marsh district. They proved satisfactorily, in the author's opinion, that none of the glacial deposits there observable were referable to Tertiary time, but all belonged either to a late Palæozoic or early Mesozoic age. They described the glaciated rock-surfaces previously discovered by Messrs. Brittlebank and Graham Officer, quoting evidence to show that the striæ trend from S.W. towards N.E., and that the ice which produced them moved in a north-easterly direction. They estimated the thickness of the glacial beds at about 5000 feet, and determined their elevations as ranging from about 700 to 1400 feet above the sea. The sandstones near the top of the glacial series contain *Gangamopteris angustifolius*, M'Coy, *G. obliqua*, M'Coy, and *G. spathulata*, M'Coy, while in shaly sandstones on a somewhat higher horizon fragments of plants resembling *Schizoneura*, *Zeugophyllites*, etc., have been observed.[4]

In November 1894 Mr. T. S. Hall[5] contributed a note on the bibliography of the Bacchus Marsh Glacial Deposits.

In January 1895 the author submitted the report by Prof. Ralph Tate, Mr. Walter Howchin, and himself on the Evidences of Glacial Action at Hallett's Cove to the Australasian Association for the Advancement of Science. This is published in the volume for 1895 issued by the Association. On April 3rd, 1895, Mr. Walter Howchin contributed a paper on the same locality,[6] in which he gives a detailed account of the glacial phenomena, and arrives at provisional deductions.

[1] Proc. Roy. Soc. Victoria, n. s. vol. v. (1893) pp. 45–68, pls. x.–xii.
[2] *Ibid.* n. s. vol. vi. (1894) pp. 139–143.
[3] Rep. Austr. Assoc. Adv. Science, vol. v. pp. 376–389, Adelaide, 1893.
[4] Annual Report of the Secretary for Mines, Victoria, for the year 1893, pp. 18–19. Melbourne, 1894.
[5] 'The Victorian Naturalist,' Melbourne, 1894, pp. 125–128.
[6] Trans. Roy. Soc. South Australia, vol. xix. pt. i. pp. 61–69.

II. Latest Observations by the Author.

(*a*) Hallett's Cove.

In December 1894 the author visited Hallett's Cove, near Adelaide, in company with Prof. Ralph Tate and Mr. A. W. Howchin, with the view of determining the question as to whether the glaciation was post-Miocene or pre-Miocene. This question had been discussed on the ground, during the meeting of the Australasian Association for the Advancement of Science at Adelaide in 1893, by Prof. Ralph Tate and a party of the members. For the purpose of finally settling the question, the Association placed the sum of £20 at the disposal of the members of their Glacial Committee, to enable them to cut a trench from the glaciated rock-pavement, across the outcropping edges of the glacial beds, up to the base of the Miocene limestone. Trenches were cut under the supervision of the above-mentioned members of the Committee, and with the permission of Mr. W. Reynell, and these excavations proved conclusively that the glaciation was pre-Miocene. These results have already been communicated by the Glacial Committee to the Australasian Association for the Advancement of Science.[1] Briefly summarized, the Report is as follows:—

The formations represented at Hallett's Cove are:—

1. Pre-Cambrian rocks, consisting of hard, purplish-red clay-slates with greenish bands, grey quartzites, and thin bands of siliceous limestone. The prevalent dip is W. 10° to 20° N. at from 40° to 78°. Wherever a fresh surface of these rocks has been exposed by the denudation of the overlying glacial beds, it is seen to be smooth and strongly glaciated, the striæ being sharply cut and as freshly preserved as though they had resulted from recent glacial action. Their trend is nearly north and south, and it is clear that the ice which produced them came from the south. The glaciated surface ascends to about 100 feet above sea-level, and descends to probably a considerable depth below the sea-level. The length of the glaciated surface preserved is about 1 mile, and its width about ¼ mile.
2. Glacial Beds, consisting of reddish-brown clay-slates, sandy in places, and fairly well stratified, especially in their upper portion. Downward they pass into sandy, greyish-brown mudstones, containing well-striated boulders in abundance: the latter occur only sparingly in the upper portion of the deposit. Erratics, chiefly of porphyritic granite, and up to 8 tons in weight, are embedded in the strata at intervals. They belong chiefly to a variety of granite occurring in place (*dixit* R. Tate) at Port Victor, 35 miles south. The glacial beds are from 23 to more than 100 feet thick, descend below sea-level, and ascend to over 100 feet above the sea. No trace of any

[1] Rep. Austr. Assoc. Adv. Science, Brisbane, 1895.

organism has yet been met with in these beds. The matrix has evidently been derived from the wearing away of the local pre-Cambrian rocks, whereas many of the erratics are foreign to the neighbourhood.

3. Miocene limestone and Miocene (?) clays. The former is separated by a slight unconformity from the underlying glacial beds. It varies in composition from that of an arenaceous limestone to that of a calcareous sandstone, having a thickness of from 2 to 3 feet. The following are some of the marine fossils contained in it, as determined by Prof. Ralph Tate:—*Plesiastræa St.-Vincenti*, Ten. Woods, *Pecten spondyloides*, Tate, *Mytilus submenkeanus*, Tate, *Pectunculus convexus*, Tate, *Conotrochus typus* (Seguenza ?). The limestone passes upward into clays, perhaps also of Miocene age, and about 60 feet in thickness.
4. Recent (?) nodular travertine, about 3 to 4 feet thick.
5. Blown sand and beach sand, resting successively on all the preceding formations.

It may be concluded that, as proved by the transport of the erratics and the grooving of the rock-pavements, the ice which produced the glaciation moved from south to north, and that it was of an age intermediate between Miocene and Pre-Cambrian. The comparatively slight induration of the glacial beds and remarkable freshness of the striæ suggest that the glaciation did not antedate the close of the Palæozoic era, as all rocks older than this in Australia are considerably indurated.

(*b*) Wild Duck Creek, Derrinal, near Heathcote.

The formations here represented are:—

1. Lower Silurian (Ordovician), which in places exhibit strongly grooved polished surfaces, the trend of the grooves being from S. 5° E. towards N. 5° W.
2. Permo-Carboniferous Glacial Beds, consisting chiefly of mudstones, with erratics up to 30 tons in weight, and sandstones. Nearly all the erratics and small boulders are beautifully glaciated, being grooved, polished, and faceted. The beds have been traced by Mr. Dunn for 15½ miles in a north and south direction, and they have a width of 5 miles. They attain an elevation of about 750 feet above the sea, and have a thickness of probably at least 300 or 400 feet. Both Mr. Dunn and Mr. A. W. Howchin are of opinion that the erratics resemble the rocks of North Gippsland in Victoria, the age of which ranges from Silurian to Carboniferous. Here, as at Hallett's Cove, the glaciation of the rock-pavements shows that the ice probably came from the south. (Photographs of the glaciated Lower Silurian rock and of the large erratic known as 'The Stranger' were exhibited at the meeting.)

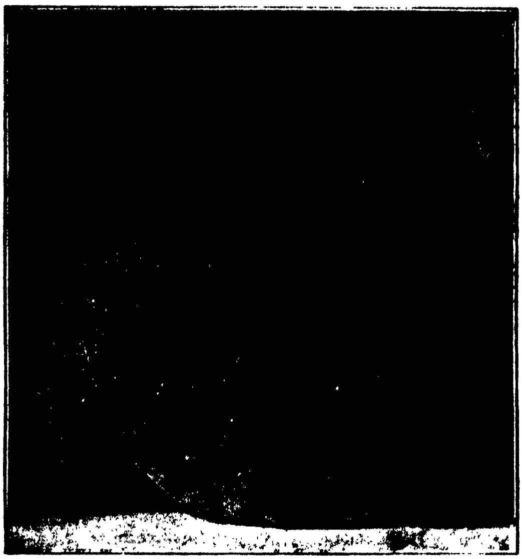
(c) Bacchus Marsh.

This district was examined by the author in company with Messrs. G. Sweet and Charles C. Brittlebank during December 1894, and again by the author in company with Messrs. C. C. Brittlebank, T. Brittlebank, Graham Officer, and L. Balfour, during December 1895. The formations represented were as follows:—

1. Lower Silurian (Ordovician), black slates and shales, with graptolites and grey quartzites intruded in places by granite. The strike is N. 10° E. to N.E., and they dip at a high angle. Wherever their surface has been freshly exposed in this neighbourhood it is seen to be strongly grooved and polished, and more or less *moutonnée*. Such striated pavements have been traced by Messrs. Sweet and Brittlebank at intervals over an area of 130 square miles in this district; and later observations by Messrs. Officer and Balfour in the Coimadai district have proved the area to be much greater. In places where the Ordovician clay-slates have had their glaciated surface destroyed by denudation, an exquisite cast of it is preserved on the under-surface of the glacial beds, accurate impressions being retained of even the most minute striæ. The surface of the pavement is very uneven, being traversed by troughs from 500 to 600 feet deep, the slopes of the ridges separating the troughs one from another being sometimes as steep as 70°. The bottoms of the troughs and the slopes and summits of the ridges are all strongly glaciated. The author agrees with Messrs. Sweet, Brittlebank, Graham Officer, and L. Balfour in their inference that the ice which produced the glaciation came from the south. At the Werribee Gorge the striæ trend from about S. 12° W. to N. 12° E.
2. Permo-Carboniferous Glacial Beds.—The thickness of these rocks has been approximately estimated, as already stated, by Messrs. Sweet and Brittlebank to be about 5000 feet, and on the occasion of the author's first examination of them it appeared that this estimate of them was not excessive. Measurements, however, taken by Messrs. Chas. C. Brittlebank, T. Brittlebank, Graham Officer, L. Balfour, and the author last December show that the thickness may perhaps have been over-estimated through a repetition of the beds resulting from faulting or folding. Their general dip is rather steep, varying from about 15° up to 60°. They consist of:—(i) Hard and soft mudstones, from brownish-grey to light claret in colour, bluish-grey at a depth. A small proportion of fragments of undecomposed felspar is present, together with minute chips of black shale (Lower Silurian ?) and small pieces of carbonized plants. The soft mudstones are chiefly composed of clayey material, with quartz-grains, mostly subangular, and contain glaciated erratics sparingly. The hard mudstones contain very numerous strongly-glaciated boulders, frequently flattened on one side as though

they had been rasped away by the ice; their diameter varies from a few inches to 5½ feet, but most of them measure less than a foot in diameter. They are very firmly embedded in the matrix, so that they can be dislodged only by repeated blows from a heavy hammer. (Several fine specimens of these glaciated blocks were exhibited, including one brought by the author as a donation from Mr. C. C. Brittlebank to the British Museum. See the accompanying figure.) The

Glaciated Boulder from the Permo-Carboniferous of Dunbar, near Bacchus Marsh, Victoria. (*About ¼ natural size.*)



[Reproduced from a photograph.]

maximum thickness of any individual bed measured proved to be 193 feet.

(ii) Conglomerates.—Greenish brown, lithologically very like those of the Permo-Carboniferous Newcastle Beds in New South Wales. They are composed of well-rolled pebbles from 1 to about 6 inches in diameter, with occasionally large glaciated erratics. The thickness of individual beds of conglomerate varies from a few feet up to about 20. In places they make a very uneven junction-line with the strata below them, as though they had been squeezed down into these so as to occupy irregularly-shaped pockets. In places the upper surface of the conglomerate is much indented, as at the elbow of Myrniong Creek, about ½ mile below Dunbar (the residence of Mr. Brittlebank).

(iii) Sandstones.—These vary from hard to soft, from fine to coarse, and are frequently laminated, the laminæ occasionally showing distinct evidence of contortion, especially in the neighbourhood of the irregular pockets of conglomerate. Individual beds vary in thickness from a few feet to nearly 100, being mostly about 30 feet thick. Well-preserved plant-remains are present on at least two horizons; on the lower horizon occur the three species of *Gangamopteris* already referred to, and on the higher specimens of *Zeugophyllites*, *Schizoneura*, etc. The total thickness of the glacial beds seen in the upper portion of Korkuperrimal Creek, as measured last December, proved to be 1427 feet. To this, Mr. Brittlebank estimates, a thickness of about 700 feet of strata should be added to carry the section from the top of the *Gangamopteris*-beds to the top of the strata seen above the *Schizoneura*-horizon. (The order of succession of the beds is illustrated in the accompanying horizontal and vertical sections, Pl. XII.)

The altitude of the glacial beds varies from 600 to about 1400 feet above sea-level. The source of the erratics is not known, but evidence shows that the ice which furrowed the rocks came, as already stated, from the south.

The most northerly point to which drift containing undoubtedly glaciated boulders has been traced is Springhurst, on the main railway-line between Melbourne and Sydney, at the boundary between Victoria and New South Wales.

III. Correlation of the Glacial Deposits.

(a) Australasian.

It is extremely probable that the glacial beds of Bacchus Marsh, Wild Duck Creek, and Springhurst in Victoria were of homotaxial, if not of contemporaneous origin. They may probably be correlated with the glacial conglomerates of Mount Reid and Mount Tyndall in Tasmania.

The above correlations are based chiefly on lithological evidence; there is, however, good palæontological evidence for the correlation of the Bacchus Marsh glacial beds with the erratic-bearing Permo-Carboniferous mudstones of Maria Island, One Tree Point, and Bruni Island in Tasmania, the similar beds at Maitland, Branxton, and Grasstree in New South Wales, and those of the Bowen River Coalfield in Queensland, as the genus *Gangamopteris* is distributed abundantly throughout the formations at all these localities. The glacial evidences at Hallett's Cove and at Curramulka in South Australia may safely be correlated one with another, and are very likely homotaxial with the above-mentioned glacial deposits in East Australia and Tasmania.

(*b*) Extra-Australasian.

The Permo-Carboniferous glaciation of Australia and Tasmania was perhaps homotaxial with that of Southern Africa and India. In Southern Africa Mr. G. W. Stow and Dr. Sutherland have described glaciated blocks associated with the Karoo or Ecca Beds. Mr. E. J. Dunn in 1872 discovered glacial conglomerates, the Dwyka Conglomerates, at Weltevreden Farm, near the junction of the Vaal and Orange Rivers; moreover, he has told me that in 1885 he discovered a striated pavement at the junction of these rivers, and was of opinion that the movement of the ice had been from south to north. This pavement is less than 1000 feet above the sea. The shales underlying the large boulders in the conglomerate are described by him as being distinctly indented. This is in lat. 29° S., long. about 23° 40′ E. Mr. Dunn has also told me that he found a specimen of *Gangamopteris* 5 inches in length in the Lower Karoo Beds above the Dwyka Conglomerates.

In India evidence of glacial action in Permo-Carboniferous time was first observed by Dr. W. T. Blanford, and subsequently similar evidence has been collected by many other observers in the Talchir Group, the Salt Range Group, the boulder-beds at Báp in Western Rajputana, and the Panjáh Conglomerates of Kashmir.[1]

Mr. Fedden [2] states that at Irai, near Chánda, the Talchir Boulder-beds rest upon compact Pem Limestones. His statement is as follows:—'For a length of 330 yards along the river's bank this underlying rock is exposed, displaying a large surface, polished, scratched, and grooved after the fashion so familiar to glacialists. The surface has a slope of 12°–15° to the west, obliquely overcutting the strata, which have a dip of 8° to the west-south-west. The striæ and grooves run in long parallel lines, having directions between north-east and north-north-east, oblique to the slope of the surface; and, from the manner in which the rock is affected at the edges of the few planes of jointing, it can be inferred that the movement was up the slope. . . . . . The actual conditions are so far confirmatory of the view we have been led to—of an ice-raft being drifted against and impelled up an opposing rock-surface. . . . . . It would appear that the freighted ice-mass had travelled a long distance from the south-west through the Utnúr and Edlabád (Idulabad) districts, where rocks occur of the same composition as that of the several boulders.'

The latitude of Irai is 19° 53′, elevation under 900 feet; the most southerly position of the Talchir Boulder-bed is stated to be latitude 17° 20′, and its altitude is given as only a little above the level of the sea.

Near Pokaran a similarly-glaciated pavement is stated to exhibit

[1] 'Geology of India,' 2nd ed. 1893, Stratigraphical and Structural, R. D. Oldham, pp. 120–121, 124, 135, 157–160, 198–201, etc. T. Oldham, Mem. Geol. Surv. India, vol. ix. (1872) p. 324; and W. T. Blanford, *ibid.* pp. 321–325.

[2] Rec. Geol. Surv. India, vol. viii. (1875) p. 17.

in addition typical *roches moutonnées* (R. D. Oldham, *op. cit.* p. 160). The marine fauna associated with the Boulder-beds of the Salt Range, and partly underlying, partly overlying them, suggests that they may be homotaxial with those of Eastern Australia and Tasmania.

This short summary of references to evidence of Permo-Carboniferous ice-action in Africa and India shows that the glacial phenomena in those regions may probably be correlated on physical and palæontological grounds with those already described as occurring in Australia, and the recent discovery of rocks of Lower Gondwana age at Bajo de Velis, in Argentina,[1] renders it not improbable that the evidences of glacial action which are recorded as having been observed in Brazil may be homotaxial with those of Southern Africa, India, Australia, and Tasmania.

IV. Provisional Deductions.

If the correlation suggested for the Australasian glacial beds be admissible, it is probable that ice-action of some kind was taking place over a large area of the Australasian region in Permo-Carboniferous time. This region extended at least from Zeehan in Tasmania, in lat. 42° S., to the Bowen River Coalfield in Queensland, in lat. 20° 30′ S., and from long. about 137° 30′ E. (Curramulka) to about 151° 30′ E. (Maitland). In Victoria many hundreds certainly, and probably several thousands, of square miles are still occupied by glacial beds, and it is likely that very large areas once glaciated have had all traces of glaciation effaced by denudation.

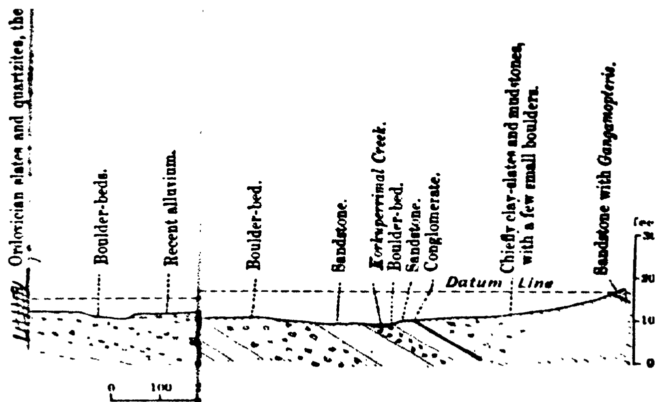
The fauna and flora associated with the Permo-Carboniferous glacial beds of Australia render it probable that these glacial beds are homotaxial with the Dwyka glacial beds of Southern Africa and the Talchir Boulder-beds of India. In the case of Australia, Southern Africa, and India, the general direction in which the ice moved appears to have been from south to north. In Australia the thickness of the glacial beds (unparalleled, so far as the author is aware, in any other part of the world, being about 2000 feet, if the intercalated beds of sandstone and conglomerate are included in the estimate) implies that the Permo-Carboniferous glacial epoch in the Southern Hemisphere was of prolonged duration. This inference is supported by the fact that in New South Wales a group of Coal Measures, over 230 feet thick, and comprising from 20 to 40 feet in thickness of coal (the Greta Coal Measures), is sandwiched in between the erratic-bearing horizon of the Lower Marine Series and the similar horizon of the Upper Marine Series.

As will be seen from the vertical section accompanying this paper (Pl. XII.), there is evidence at Bacchus Marsh of at least from nine to ten distinct boulder-bed horizons, separated one from another by thick deposits of sandstone and conglomerate. The exact significance of

[1] Rec. Geol. Surv. Ind. vol. xxviii. pt. iii. (1895) pp. 111–117, and Revista del Museo de la Plata, vol. vi. pp. 117 *et seqq.*

ial Beds, Ba

am Officer, revising it).



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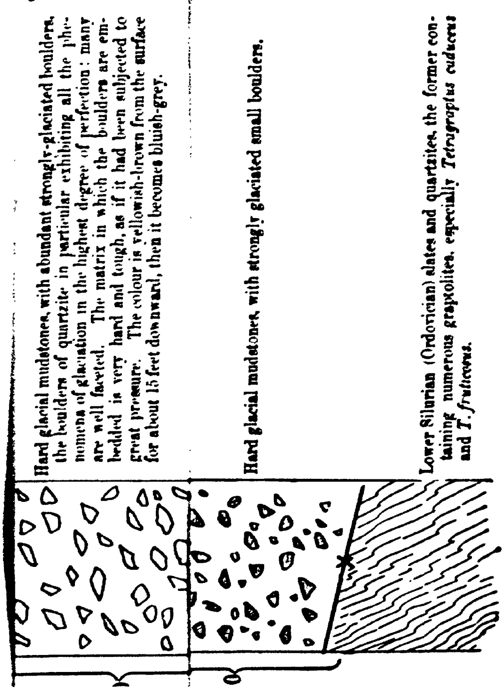


these lithological breaks in the succession of strata is not yet understood, but they may possibly indicate a sequence of glacial epochs separated by milder interglacial periods. Possibly glacial conditions in Australia may have been prolonged from late Palæozoic into early Mesozoic time, as may perhaps be argued from the presence of plants of Mesozoic facies, such as *Schizoneura* and *Zeugophyllites*, in the uppermost glacial beds of Bacchus Marsh, and also perhaps from the disrupted masses of clay-slates and contemporaneously-contorted current-bedding in the Triassic Hawkesbury Series of New South Wales.

EXPLANATION OF PLATE XII.

Horizontal and vertical sections of the Permo-Carboniferous Glacial Beds at Bacchus Marsh (Victoria).

Discussion.

Dr. Blanford referred to the peculiar interest that he took in the paper, as he had, nearly 40 years ago, called attention to the existence in India of rocks similar to those described in Australia, and of the same age, and had suggested a glacial origin for them. He heartily congratulated the Author on his admirable paper and on the conclusive evidence of glacial action now brought forward, evidence so clear that it was doubtful whether a sceptic remained among those who had attended the meeting. The speaker proceeded to give a few details of the progress of discovery in India, and referring to the evidence gradually accumulated from Australia and South Africa, especially noticed how in the Argentine Republic of South America all the peculiar Upper Palæozoic and Mesozoic floras of Australia—the Carboniferous flora with *Lepidodendron* and *Rhacopteris*, the Permo-Carboniferous with *Glossopteris* and *Gangamopteris*, and the Lower Mesozoic with *Thinnfeldia odontopteroides*—had been discovered one after another, and how their constant associates in other lands, the boulder-beds, appear to have been found by Prof. Derby in Southern Brazil. He pointed out the connexion between these discoveries and the question of the former distribution of land, and called attention to a recent paper by Mojsisovics, Waagen, and Diener, who showed that while the present contours of the Pacific Ocean were of pre-Triassic age, those of the Indian and Atlantic Oceans appeared to be of later origin.

Mr. Wickham King and Prof. Bonney also spoke, and the Author replied.

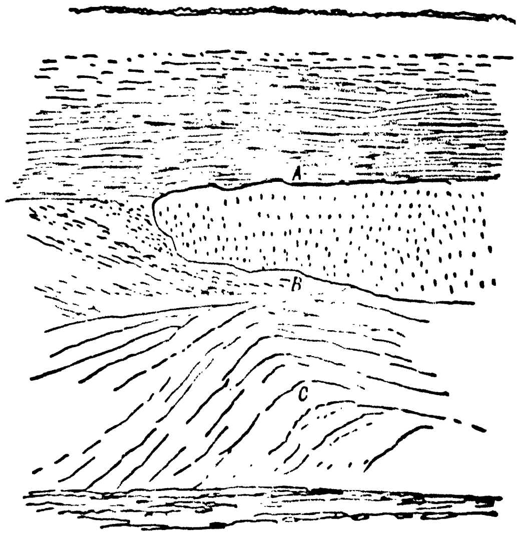
16. *On* Transported Boulder Clay. By the Rev. Edwin Hill, M.A., F.G.S. (Read January 22nd, 1896.)

I wish to put on record some facts lately observed respecting two groups of Boulder-Clay masses which appear to have been transported from their original positions.

One group occurs in the cliffs south of Great Yarmouth. The sands of the cliffs which extend from Lowestoft to Yarmouth are usually described as 'Mid-Glacial.' On them lies Chalky Boulder Clay as seen at Corton and northwards, while below them are seen at several spots a perfectly different stony clay, the sands called Pebbly Sands or Westleton Beds, and the well-known Rootlet Bed. The Chalky Boulder Clay extends continuously above the Mid-Glacial sands, from Corton for about ¾ mile northwards; farther on, one or two disconnected strips also lie on the top of the cliffs. But, besides these, several masses of the same material occur embedded in the sands. I first noticed them while examining the coast in 1893, and in the spring of 1895 I again made a careful inspection, this time in company with Prof. Bonney. Two lie one on either side of the depression called League Hole, and others were seen respectively about ½ mile, 1 mile, and 1½ mile north, towards Gorleston. The writer of the Survey Memoir (Mr. J. H. Blake) had his attention attracted to these or similar masses, and remarks that 'at times they looked as if they were lenticular patches of Boulder Clay in the Glacial Sands' (p. 56, Geology of Country near Yarmouth and Lowestoft). He decided, however, that 'they were all introduced after the deposition of the sands.' He does not explain how; probably he means that they had fallen from the top of the wasting cliff, and had become buried in talus or blown sand. If he had seen the sections exposed in 1893 and 1895, I think he would have concluded that they really were what he then saw that they looked like.

The mass about 2 miles south of Gorleston Pier, or ½ mile north of League Hole, as seen in the cliff-section, was about 4 feet thick, with 40 feet of visible length (see fig. 1). Its northern end was hidden by talus, but on the south it was seen, in a clean section of the cliff, ending abruptly against the sands, which presented their regular stratified appearance, and were in undisturbed contact with it above and below. It was normal Chalky Boulder Clay, crowded with fragments of chalk. The mass about 1½ mile south of Gorleston Pier had a very dark matrix, full of rather rounded chalk pieces of all sizes, from a foot long down to the finest grains; it contained also some larger inclusions of sand or silt. This mass was about 6 feet thick, also with visible stratified sands above and below. Here, too, one end was hidden under talus; the other passed into the sands in tongues and strings of dark mud, but the termination of these was again hidden by talus. The mass about 1 mile south of Gorleston was some 30 feet long; one end

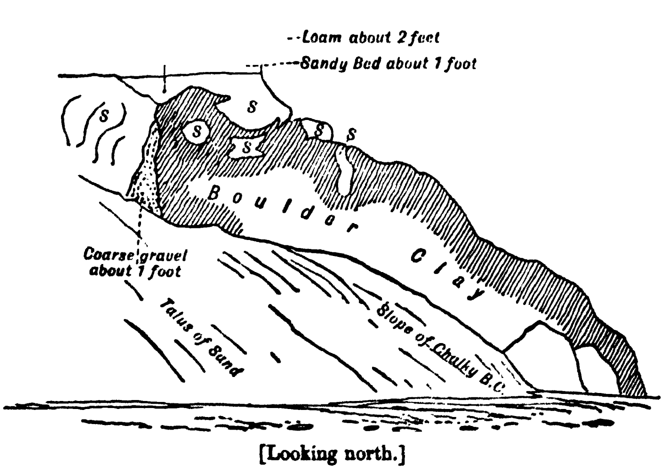
Fig. 1.—*Section ½ mile north of League Hole.*



A-B = about 4 feet. C = talus.

The dotted part is Boulder Clay, extending horizontally to the right for about 20 feet. Above and to the left of B, fine-bedded sand, with little lumps of Boulder Clay in it. More disturbed in the upper part.

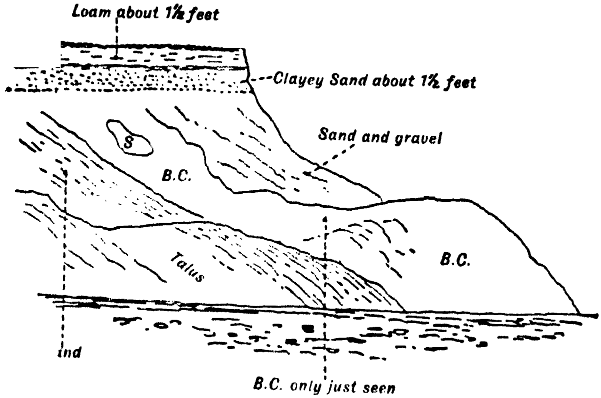
Fig. 2.—*Section immediately north of League Hole. (Total height = about 18 feet.)*



[Looking north.]

is bent up, and both ends thin out; it is only 6 feet below the top of the cliff, and there is a layer of large flints above. In the masses at League Hole there are signs of slipping, yet here also there is sand overlying them, which I could not distinguish from the adjacent Mid-Glacial sand.[1] Along the beach, among the masses

Fig. 3.—*Section in the little headland, near League Hole.* (*Diagrammatic.*)



[Looking west.]

BC = Boulder Clay. S = Sand.

fallen from the cliff, pieces of Boulder Clay here and there occur, where none can be seen on the cliff-top; these also probably have come from the interior of the sands. The cliff is annually wasting, so that the visible sections and their appearances are in a state of constant change.

All the masses within consist of normal Chalky Boulder Clay crowded with fragments of chalk. They all pass into the sands in tongues, strings, or separate patches of a dark wet mud, like the clay of the matrix, but containing no chalk. The mass nearest Gorleston has many such streaks and patches, usually about 12 inches by 2, in the underlying sand, to a depth of about 3 feet. Even the mass first described, which, seen from the beach, seems to end abruptly, on near inspection is found to have some of these patches lying close to it in the sands. I do not see how these masses could have been formed *in situ*. The appearances agree, however, in all respects, with what would be expected if masses of Boulder Clay surrounded by ice had been floated over the waters in which the sands were being deposited, and had sunk where we find them. The

[1] [For figs. 1, 2, and 3 my thanks are due to Prof. Bonney, who kindly furnished them from his note-book. The sections at League Hole show that the masses terminate in the interior of the cliff as well as in its face.]

buoyancy of the ice would make the masses at first practically weightless in the water, so there would be nothing to press down the floor on which they sank. As the ice melted away they would acquire weight, but meanwhile deposition would be going on all round. As the encompassing ice melted still further, portions of the outside would break away: hence the patches. Mud also from the wet outside would ooze off and spread on the sand floor, forming the tongues and strings. In all these the chalk would have disappeared, as it has disappeared from recomposed Boulder Clay, and generally from parts where water can percolate. Meanwhile the progress of deposition would have intermixed sand with the patches, tongues, and strings in undisturbed stratification.

The other group of transported masses is different in character, date, and locality. The group came under my notice in my own parish (Cockfield, Suffolk). Here is a series of pits, containing a peculiar gravel, which I have traced along a line of about 7 miles, through the parishes of Bradfield, Stanningfield, Cockfield, and Lavenham. Their contents resemble descriptions of 'Cannon-shot Gravel': they lie at corresponding levels along the slope of an existing valley, which is hollowed out of Chalky Boulder Clay; and they probably mark an earlier water-course. They clearly indicate extensive denudation of the Boulder Clay, for the slopes of that formation rise from 40 to 60 feet above them; also the flints which it contains are clean of chalk, and have undergone considerable wear. In two of these pits, one near Cockfield 'Abbey' and one near Willow Bridge (the latter lately filled in), masses of Boulder Clay are found lying on the top of the gravel.

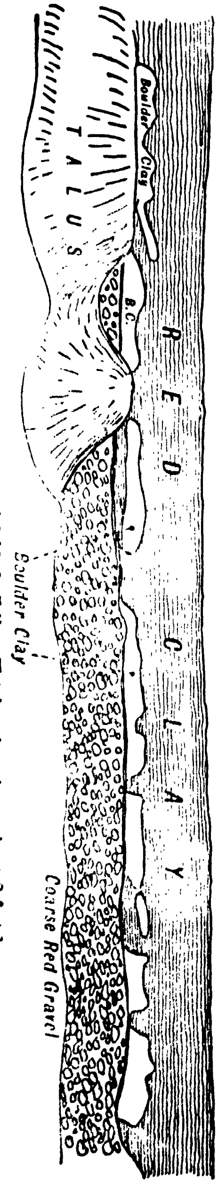


Fig. 4.—Patches of Chalky Boulder Clay in red clay, resting on coarse gravel.

[Pit near Willow Bridge, Cockfield, Suffolk. Height of section = about 8 feet.]

In the Willow Bridge pit the clay was 2 or 3 feet thick and extended some 50 feet; whether continuously or in several adjacent masses was uncertain: appearances were in favour of the latter view, but it was difficult to decide on the nature of decomposed interruptions. The outsides and the decomposed portions are a reddish clay or earth, but the cores are perfectly normal Chalky Boulder Clay, with much chalk, in pieces from 2 or 3 inches long down to pea-size and grains.

It seems impossible to suppose that the agent which produced the Chalky Boulder Clay, after ceasing to operate during the long interval indicated by the gravels, again set up work and produced these scanty fragments. The pits described lie on the side of Boulder Clay slopes which rise, though gently, to considerably greater heights. A natural explanation is that the masses have come from higher ground, floated off or slipping down, in either case probably in a frozen state. Between them and the gravel lie seams of a finer clay, and over them something of the nature of brick-earth; while brick-earth is also abundant and worked at nearly the same level midway between the two gravel-pits named. Under the coarse gravel, in another of the pits, lie highly false-bedded white gravel and sand. Thus there is abundant evidence of contemporary water-action, and everything agrees with the view that these seams of clay have been brought, not formed *in situ*.

If these conclusions are established, some consequences follow. The writers in the Survey Memoirs on East Anglia frequently mention beds of Boulder Clay in unusual positions, intercalated in, or overlying, sands and gravels. May not many of these be also transported sheets? If so, difficulties which the writers evidently felt may be removed. Again, must not much caution be observed in attributing an 'interglacial' age to beds, fossils, or implements found beneath thin sheets of Boulder Clay, especially where this occurs also at higher elevations in the neighbourhood?

The Lowestoft instances would show that while in one locality sands, called 'Mid-Glacial,' were being deposited, in some other locality the manufacture of true Chalky Boulder Clay had already been commenced and perfected, so that exportation could go on. I do not see that they give any evidence of the process of manufacture. They are not unlike the pieces which might break off from the clay-banks of a Siberian river:—but I must not wander far into the field of conjecture.

Discussion.

Mr. H. B. Woodward suggested that in Mr. Hill's Corton section the Boulder Clay might occur in the form of an intrusive tongue; and in the West Suffolk section the isolated patches of Boulder Clay might be remnants lying beneath a mass from which the chalky portions had been removed by dissolution—a feature common in the Eastern Counties.

Prof. Bonney said that he had carefully examined the section south of Yarmouth with Mr. Hill, and could not find the slightest evidence of intrusion of the Boulder Clay—a thing, by the way, of which he

never could find evidence—but here the masses occasionally passed in strings into the sand, and small boulders of clay occurred in the sand below. Whatever might be the explanation, he could come to no other conclusion than that the clay-masses were true boulders.

Dr. Du Riche Preller suggested, from the description given by the Author, that the Boulder Clay wedged in between sand, as shown in the first section, was probably deposited during an oscillation of the drift-ice, the similar effect of such oscillations being frequently apparent in the Alpine glacial deposits, which were, of course, the product of land-ice. He had recently examined some of the Boulder Clay of West Norfolk near Lynn, which was absolutely different from the glacial clay of the Alps, and, in his opinion, was clearly the product of drift-ice.

Mr. Lamplugh was reminded by the section on the wall of what he had seen some years ago on the flank of the Muir glacier in Alaska, where a strip of ice loaded with débris overran stratified gravels without disturbing them. The presence of thin strips of clayey material in gravels was a common phenomenon in Glacial deposits, and he saw no difficulty in accounting for them as the product of the edge of an ice-sheet. The admirable descriptions given by the American geologists, especially by Messrs. I. C. Russell and T. C. Chamberlin, of the great glaciers of Alaska and Greenland came as a revelation on many points to the students of glacial geology, and deserved the closest study.

The Author said that to suggest an ice-sheet as the cause of the insignificant fragments of Boulder Clay upon the gravels was like suggesting a steam-hammer as the cause where a few bits of nutshell had been found.

17. Observations *on the* Geology *of the* Nile Valley, *and on the* Evidence *of the* Greater Volume *of the* River *at a* Former Period. By Prof. Edward Hull, M.A., LL.D., F.R.S., F.G.S. (Read February 26th, 1896.)

Part I.

1. Introductory.

The evidence in favour of the view that the Nile was at one period a river of vastly greater volume than at the present day is so remarkable that it has forced itself on the attention of several writers, amongst whom may be specially mentioned the late Prof. Leith Adams,[1] Prof. Zittel,[2] and Capt. Lyons[3]; and to the statements coming from such competent observers I should hardly have thought it necessary to add any of my own, were it not that I find from personal intercourse that geographers have failed as yet to grasp the full significance of the phenomena bearing on the subject and described by the above-named authors. When about to leave for a recent visit to the Nile Valley, I wrote to Prof. (now Sir) Joseph Prestwich, enquiring whether he thought there were any problems to which a travelling geologist might give attention with some prospect of enlarging our knowledge of the physical conditions of that remarkable line of country, and in reply he recommended me to pay special attention to the terraces. This advice I endeavoured to keep before my mind during my ascent as far as the First Cataract and the return journey; and I venture to lay before the Society the impressions that I then received, and the conclusions that I have drawn from them regarding the volume and dimensions of the river at a prehistoric period. But, before entering upon this special subject, I wish to note a few points connected with the geological structure of the Nile Valley, which came under my notice, although they may not be altogether new.

2. Some Points in the Geology of the Nile Valley.

And first let me observe that it is only by personal examination that one can realize the extent of the erosion by old river-action which was carried on after the Libyan region had been elevated out of the waters of the sea at the close of the Eocene period. That this erosion was accomplished mainly during the succeeding Miocene

[1] Leith Adams, 'On the Geology of a Portion of the Nile Valley, etc., with Note on the Shells, by S. P. Woodward,' Quart. Journ. Geol. Soc. vol. xx. (1864) p. 6.

[2] Zittel, 'Beiträge zur Geologie und Paläontologie der Libyschen Wüste,' Palæontographica, vol. xxx. pt. i. 1883.

[3] Lyons, 'On the Stratigraphy and Physiography of the Libyan Desert of Egypt,' Quart. Journ. Geol. Soc. vol. l. (1894) p. 531.

period, upon the rising of the land, there can be little doubt; as it is becoming more clear that this was the special epoch of elevation, disturbance of strata, and denudation over all the Egyptian and Syrian region.[1] But there was a second period of great fluviatile inundation in what may be designated 'the Pluvial period,' extending from later Pliocene times into, and including, the Pleistocene; and to this latter stage I shall have occasion to recur later on. At the present day erosion has almost ceased, and the fact that the cultivated terraces bordering the river, as well as the plain of Lower Egypt, are gradually rising with regard to the sea-level by reason of deposition of sediment shows that the bed of the river is also rising.[2] There is, therefore, no scouring action going on.

The fall of the river from Assuân to Cairo is a little over 6 inches per mile, a fall just sufficient to keep the fertilizing sediment in suspension when the river is not at its lowest. The magnificent Nile Valley, of an average breadth of 10 miles, cut down through a table-land of an average elevation of 800 to 1000 feet, capped by Eocene limestone, and extending above Cairo for a distance of 300 miles, is a physical feature which must impress the observer with the conviction of the enormous length of time during which the Miocene erosion was in progress.[3]

The next point to which I wish to refer is the fact that in the Nile we have a conspicuous example of a river running across escarpments. Taking these in succession from the north up stream, they are:—1, the escarpment of the Eocene limestone; 2, that of the Cretaceous limestone; 3, that of the Nubian Sandstone; and 4, in a less degree, that of the granitic and schistose rocks of Assuân. The dip of the strata towards the north, although generally almost imperceptible, and sometimes reversed, is greater than the slope of the river-channel. In consequence of this the transverse course of the river was a physical necessity, if it was to enter the Mediterranean; but owing to the low angle of dip of the beds, and their wide range, the fact is not so evident as it would be if the dip were greater, and the range more contracted. Zittel has suggested that the river once entered the Red Sea. This I cannot conceive to have been possible at any point above Cairo, except during early Pliocene times when Lower Egypt was submerged to a depth of about 220 feet, and the waters of the Red Sea, united to those of the Mediterranean, overflowed the entire region below this level. In this sense the statement is true, but not otherwise. As in the case of the streams traversing the Chalk and Greensand escarpments in

[1] It is now becoming generally recognized that Miocene strata are absent from the Egyptian area, which bears out the view above stated. See 'The Geology of Egypt,' by Philip Lake, 'Science Progress,' vol. iv. (1896) p. 395; also Prof. Mayer-Eymar, 'Zur Geologie Aegyptens,' Vierteljahrschr. Naturf. Gesellsch. Zürich, 1886.

[2] Otherwise the river would have ceased to reach the cultivated plain on its banks.

[3] From Zittel's section across the Nile Valley it will be seen that the plateau on the eastern side of the valley rises over 1500 feet in some places, and I am inclined to think that the average height may be 1000 feet.

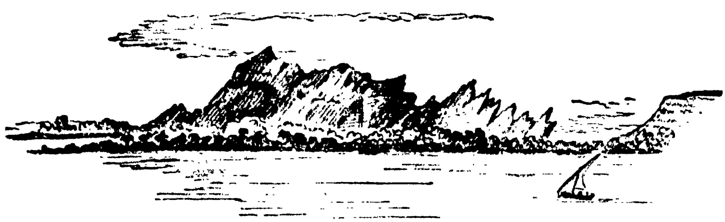
the Wealden area, once the course of the river had been selected as the land emerged from the ocean in Miocene times, that course was never abandoned. The physical features of the region between the Nile and the Red Sea are quite inconsistent with such an hypothesis as that referred to.

3. Faults.

Besides a depression along the general course of the Nile Valley in the surface of the Eocene and Cretaceous beds, which must have guided the original course of the river northward, faults appear to have played an important part. They have been noticed by Dawson,[1] E. H. Johnson and H. D. Richmond,[2] Lyons,[3] and others. That which follows the line of the valley above Cairo has long been known.

Another remarkable fault is shown on the right bank about 5 miles below Farshût, following the course of the stream, with the downthrow on the western side, along which the beds are highly tilted and bent. A third case at Gebel Ain, above Luxor, is remarkable for the high angle at which the beds are seen to dip (fig. 1). This is visible in the left bank of the river, and appears to follow its course in that locality.

Fig. 1.—*Sketch at Gebel Ain, showing beds of limestone highly tilted along line of fault.*



[The escarpment of Eocene limestone is in the background to the right.]

I refer to these cases merely in order to show that the line of erosion of the primæval Nile was sometimes directed by the dislocations of the strata; but some of the faults are transverse to those which run parallel to the course of the stream, such as that at Maghâghah.[4]

[1] 'Modern Science in Bible Lands,' Appendix, 1888.
[2] Quart. Journ. Geol. Soc. vol. xlviii. (1892) p. 482.
[3] *Ibid.* vol. l. (1894) p. 541.
[4] Described by Johnson and Richmond.

4. Relation of the Nubian Sandstone to the Granite and Schist of Assuân.

The only other point bearing on the geology of the Nile Valley to which I shall refer is the relation of the Nubian Sandstone to the older rocks of Assuân and the First Cataract. I should not have thought it necessary to do so, had not some observers supposed that the granite is intrusive into the newer formation. From an examination of the junction at several places, I have satisfied myself that there is no good warranty for this view. Undoubtedly the original surface of the older rocks was very uneven, consisting of ridges and furrows against, and upon, which the Sandstone Series was deposited. But the latter is not in the least 'baked' or 'altered' along the surface of contact, while the local basement-beds are often conglomeratic, pebbles of quartz, probably derived from the granite itself, being abundant. The junction is remarkably well shown above the ancient quarries, along the pathway leading to the barracks which overlook the Nile Valley, and the accompanying sketch was taken on the spot.

Fig. 2.—*Sketch of junction of granite and Nubian Sandstone near the Barracks, south of Assuân.*

1 = Coarse brown grit.
2 = Grey and purple sandy shale (10 feet).
3 = White freestone, coarse to fine, with quartz-pebbles.

G = Granite, weathering into rounded masses.

B = Basalt-dyke, 8–10 feet wide.

The general structure of the locality is illustrated in the above section, taken from the banks of the river opposite the Island of Sehêl, about 3 miles south of Assuân.

5. Age of the Nubian Sandstone.

I shall not enter here on the question whether the whole of the Nubian Sandstone of the Nile Valley is of Cretaceous age, or whether it is partly Carboniferous. It is a problem which can be solved only by a careful survey of the whole region, which, as announced, is to be immediately undertaken by the Egyptian Government, under the direction of Capt. Lyons. I will only observe that some portions of the formation which I was able to examine in the Nile Valley are very unlike in mineral composition

to the Nubian Sandstone of Cretaceous age in Arabia Petræa and the Arabah Valley. This, however, is not surprising, considering the distance by which the two localities are separated, and does not afford any evidence that the formations are of different geological ages. In Arabia Petræa and along the eastern side of the Wadi-el-Arabah, the Nubian Sandstone is distinguished by rich red and purple or yellow colouring; the base is a conglomerate where it rests upon the crystalline rocks, and bands of clay or marl are rare.[1] On the other hand, as Lyons has shown, bands of clay are common in the Nubian Sandstone of Upper Egypt,[2] while the prevailing tint is light grey or brown, sometimes slightly tinged with red or pink. It is this stone which was so largely used in the building of the temples, and which has wonderfully resisted the effects of time.

Part II.

6. The Levels of the Ancient Nile.

The evidence upon which the former greater volume of the Nile waters is inferred may be considered under two heads: (1) the river-terraces now beyond the reach of the highest floods, and (2) the old river-channels through which the waters cannot now pass, owing to difference of level. We shall consider these separately.

(1) *The River terraces.* In order to arrive at a clear knowledge of the bearing of this subject upon the question of the former volume of the Nile, it may be observed that the general structure of the valley as far as the First Cataract is, on the whole, remarkably uniform and simple. First, we have the valley itself shut in on either hand by the escarpments along which the plateaux of the Libyan and Eastern[3] deserts terminate; then, from the base of [illegible] ing terrace, formed of alluvial gravel, sand, or mud, of varying breadth, and terminating along a well-defined bank rising above a lower terrace which, in turn, breaks off along the banks of the river. This lower terrace (No. 1) consists of Nile mud, is richly cultivated or planted with palms or other trees, and is watered by the Nile inundations. The terrace above (No. 2) is absolutely destitute of vegetation, and its surface, formed of yellowish gravel or sand, contrasts in a striking manner with that of the lower terrace above which it rises. Other terraces at higher levels there may be in Middle Egypt, connected with the epoch of Pliocene submergence,[4] of which I shall have to speak presently; but the above

[1] 'Geology of Arabia Petræa,' Mem. Palest. Explor. Fund (1886), p. 54.

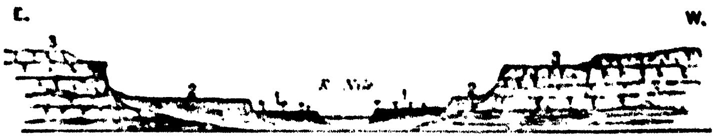
[2] Quart. Journ. Geol. Soc. vol. l. (1894), p. 5[illegible].

[3] Generally called in the maps 'the Arabian Desert,' because largely inhabited by Arabs, but the name is misleading.

[4] Or during the emergence of the Miocene period, and represented by the caves and terraces at levels of about 300 feet described by Sir J. W. Dawson, 'Modern Science in Bible Lands,' Appendix, 1888, p. 341; and Geol. Mag. 1884, pp. 289-92.

description applies, with slight modification, to the whole valley as far as Assuân, and also between this and the Second Cataract, as may be gathered from the descriptions of Prof. Leith Adams and Capt. Lyons. The following section, taken across the valley at Farshût, is intended to show its general structure:—

Fig. 3.—*Section at Farshût.*



Terrace 1.—Liable to floods. Cultivated.
Terrace 2.—Older. Beyond the reach of floods.
Terrace 3.—Plateau of Eocene limestone at the border of the

That terrace No. 2 was originally the bed of the Nile there cannot be a doubt, and the occurrence of fluviatile shells in the strata is not required to strengthen this view. These were found by Leith Adams both above and below the First Cataract. Where I examined the beds, at Thebes and Assuan, I was not so fortunate as to find them. I will now mention a few localities where terrace No. 2 may be observed above Girgeh.

(*a*) *Girgeh.*—Where the valley widens a short distance above Girgeh, terrace No. 2 is distinctly seen, rising, say, about 80 to 100 feet above the cultivated terrace (No. 1). The level is rather higher than that farther up the valley. This may be accounted for by the Pliocene submergence, which would have affected the level of the river nearly as far as Girgeh; to this I shall again have to refer.[1]

(*b*) Above Kasr es-Sayad the western escarpment of the Eocene limestone recedes for a great distance from the river-side, and here

[1] Dawson believes that the sea-waters reached as far as the First Cataract, supposing the 220-foot caves and terrace above the Nile at Gebel Mokattam to be due to submergence which is uncertain in the absence of marine forms at this level. But the only certain raised sea-beach—that discovered by Prof. Fraas—is nearly 200 feet lower, and the sea-waters in this would not have reached farther than Girgeh, as above stated.

[For this determination I am indebted to Mr Garstin, Chief of the Egyptian Public Works Department, who kindly sent me the following statement while this paper was passing through the press:—

'Distance from Cairo in kilometres at which the high water level was 220 feet over the sea:

1890 = 562 kilometres from Cairo
1891 = 563 " "
1892 = 558 " "
1893 = 563 " "
1894 = 570 " "
1895 = 564 " "

'The mean is 563 kilometres from Cairo' or 339.57 miles. This distance would reach to within 2 miles of Girgeh, which is 341½ miles from Cairo.—April 25th, 1896.]

both the cultivated plain and terrace No. 2 extend over very large areas. The latter is very distinct, rising in a bare yellowish slope of 40 to 50 feet (estimated) above terrace No. 1, and stretching to the flanks of the valley.

(c) On the right bank of the Nile at El Kab, about 15 miles south of Esneh, both terraces are clearly defined. Here a village of mud-huts is built upon terrace No. 2, below which is the cultivated flat, and behind rises a fine cliff of Cretaceous limestone.

(d) The sloping plain on which was built the city of Thebes is referable to the second terrace. It consists of beds of sand and gravel, laid open near the temple of Medinet Abu, bounded inwards by the grand semicircular escarpment of the Eocene beds, and towards the river by the wide plain, richly cultivated and abundantly watered at Nile flood. From this plain rise in solitary grandeur the Colossi of Memnon,[1] and as it is improbable that they were originally (over 3000 years ago) erected on a basis liable to the floods of the Nile, we have here evidence that the bed of the river and the plains on its banks have been raised by repeated depositions of sediment;—an inference borne out by other examples of a similar kind. Terrace No. 2 forms a wide plain west of Thebes, but it becomes very narrow at Kurnah in the opposite direction. From this neighbourhood, at El Waddi, Gen. Pitt-Rivers obtained some flint flakes supposed to be of human workmanship, embedded in banks of undisturbed gravel.[2]

(e) Opposite Kom Ombo, on the western bank of the river, the floor of the old Nile is laid open on the banks of the river itself, and is peculiarly interesting, as it is composed of laminated brownish mud lying at the foot of a range of sandhills, and rising from 30 to 50 feet above the margin of high Nile. I give here a sketch of this interesting section, which was pointed out to me by Capt. Lyons.

Fig. 4.—*Terrace of Old Nile mud near Kôm Ombo.*

1. Low terrace of clay, covered with vegetation.
2. Old terrace of Nile mud, laminated (30 to 40 feet above the highest floods).
3. Bank of sandhills. Nile in foreground.

[1] 1300 B.C. according to Dr. Budge, 'The Nile,' 3rd ed. p. 13; 1400 B.C. according to Prof. Rawlinson, 'Ancient History,' p. 39.

[2] Journ. Anthrop. Inst., May 1882, quoted by Prestwich, 'Geology,' vol. ii. p. 483. Dawson, however, doubts that these were the work of man ('Modern Science in Bible Lands,' Appendix, 1888, p. 541).

In some places, between Silsileh and Assuán, the second terrace seems to merge at the surface into the low terraces of the Nubian Sandstone, the grand escarpment of the Eocene limestone having given place to the Nubian Sandstone. In this district Leith Adams discovered numerous river-shells at a level of at least 120 feet above the highest Nile of the present day.[1]

(*f*) *Old terraces above the First Cataract.*—According to Leith Adams, the old terraces now rising far above the highest floods of the Nile at the present day may be traced at intervals along the valley between the First and Second Cataracts. One of the most remarkable instances occurs at Derr, the capital of Nubia, about 80 miles below the Second Cataract. Here, above the cultivated terrace liable to floods, rises a cliff of sandstone, above which is a second sloping terrace, rising from 110 to 130 feet above highest Nile, formed of pebbles, among which Adams found numerous specimens of *Cyrena fluminalis*, a shell now abundant in the Nile waters. Some miles farther northward, in the same terrace, the same shell was found in reddish sandy soil, together with *Bulimus pullus*. Similar terraces were recognized at Gharbea, north of Korosko, at Dakke and Gertassee, rising from 60 to about 100 feet above the highest Nile floods, and containing several species of fresh-water mollusca.[2] These observations are confirmed by Capt. Lyons, who speaks of the large sheets of gravel, which in Nubia extend for a length of 7 or 8 miles along the Nile bank at Debera, 8 miles north of Wadi Halfa, at 100 feet above the present Nile floods, and containing shells, such as *Ætheria semilunata*, *Cyrena fluminalis*, *Unio*, and *Paludina*.[3]

(*g*) But these evidences of former higher levels do not cease at the Second Cataract, for Capt. Lyons has shown,[4] by the position and inscriptions on the rocks and temples dating as far back as 2200 B.C., that the river then rose to a maximum of 27 feet above its present flood-level: the amount of rise decreasing as time went on. Lyons suggests that these variations of the river were caused by earth-movements; but it seems more probable that they are referable to the same general causes as those which have given rise to the high terraces occurring at intervals down the valley into Lower Egypt.

Thus we have seen that, throughout a distance of between 600 and 700 miles above Cairo, the evidence derived from the terraces is cumulative, and tends to prove that the original surface of the Nile waters stood at a level varying from 50 to 100 feet or more above that of the present day.

PART III.

7. Old River-Channels.

How many channels of the primæval Nile there may be which the river has deserted in consequence of the fall of its surface I

[1] Quart. Journ. Geol. Soc. vol. xx. (1864) p. 9.
[2] Ibid. pp. 13, 14.
[3] Ibid. vol. l. (1894) p. 543.
[4] Ibid. p. 544.

am unable to state, but we are happily in possession of exact information regarding two of them: one at Kom Ombo, about 26 miles below Assuan, and one at this latter place itself. Of these I now proceed to give some detail.

(1) Kom Ombo (or Kom Ombos).—The remarkable ruins of two temples perched on a cliff overhanging the river, which is constantly being undermined, and is threatened with eventual destruction, derive much interest from the fact that they are built on the alluvia of the old Nile, and formed part of its ancient bed before the waters had fallen away to their present level. The surface of the highest Nile-floods does not reach to within more than 12 metres (39·36 feet) of this old terrace, as stated by Mr. W. Willcocks, of the Egyptian Public Works Department,[1] and both he and Leith Adams discovered shells of the genera *Cyrena* (*Corbicula*), *Unio*, and *Paludina* in the alluvial beds at a level of 11 metres (36·08 feet) above present highest floods. In order to compare the relative levels of the floods of the present day with those of the ancient river at this place, we ought to add about 30 feet to that of the floor, which will show a difference of about 70 feet for the respective surfaces.

(2) Assuan, which is built on the cultivated terrace at the northern or lower end of the First Cataract, is connected with Shellal at the southern or upper end, not only by the river, but by two valleys, one or both of which were probably river-channels when the river flowed at a higher level. They lie parallel to each other and to the Nile itself on its eastern side.[2] Of one of these only can I speak with certainty, time not having allowed me to make a proper examination of the other. Along this, the more easterly of the two valleys, the railway connecting Assuan and Shellal is carried for a distance of about 7 miles. It is about half-a-mile wide, running between rugged slopes of granite capped by horizontal courses of Nubian Sandstone. The floor of the valley is even, affording camping-ground for a tribe of Bedawin Arabs, and is composed of sand, gravel, and mud rudely stratified.[3] The surface rises to a low saddle about 2 miles south of Shellâl, the height of which has been kindly determined for me by Capt. Lyons by levelling to be 93·44 feet (28·48 metres) above highest floods at Shellâl and the island of Philæ, which is opposite this village; and here, again, if we wish to compare the original height of the water-surface with that of the present day, we may add, as a safe estimate, 25 or 30 feet—making 108·44 feet as the amount of difference of surface during high floods. This level exceeds that at Kom Ombo, but may be accounted for by the difference in the physical conditions of each place; the Nile being here narrowed and encumbered

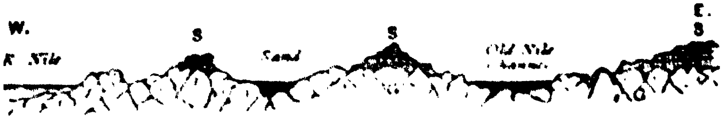
[1] Report to the Government of Egypt on 'Perennial Irrigation, etc.,' 1894. Appendix vii. p. 18. Willcocks has also noticed *Ætheria elliptica* in the old Nile deposits both above and below Cairo; Sawadeh, *ibid.* p. 14.

[2] Baedeker's 'Guide to Upper Egypt' contains an excellent little map of the environs of Assuân (ed. 1892, p. 274).

[3] My first visit to this valley was in company with Capt. Lyons, who indicated its origin as an old Nile valley, a view which a subsequent visit fully confirmed.

by granite ridges, instead of having merely to find its way through a wide plain as at the latter place. Near the northern end of the railway-cutting above Assuan we find a deposit of the old Nile mud with bands of pebbles resting on the upturned edges of the ancient schists.

Fig. 5.—*Section from the river-bank opposite the Island of Sehêl at the First Cataract.*[1]



S = Nubian Sandstone and Conglomerate
G = Granite forming the sides of the present and ancient channels of the Nile.
[Distance = over 2 miles.]

The valley now described was recognized by Leith Adams as an ancient river-channel, and in the alluvial deposits in the ravines north of it he was fortunate in discovering numerous shells, such as *Ætheria semilunata*, *Iridina nilotica*, and *Bulimus pullus*.[2] Time did not permit of a careful search on my own part.

From the foregoing facts and considerations it will be observed that the evidence of a former higher Nile surface afforded by the old terraces is confirmed by that of the old channels. The waters which formerly extended over the floor of the Nile Valley with a breadth of several miles are now confined by banks which are seldom ½ mile apart, and this has resulted, not in consequence of the deepening of the channel, but by reason of the diminution in volume of the waters themselves. This is shown by the fact that there is no scouring of the Nile channel, the current being insufficient for this purpose; and besides this, the borings which have been made show that the bed of the river is composed of alluvial mud of considerable depth.[3] The bed is, in fact, rising by accessions of deposit comparable with that which is annually spread over the cultivated lands on either side during the high floods, and which has been estimated by Mr. Willcocks, Engineer to the Public Works Department, to amount to 0.12 metre (4.7 inches) in 100 years.[4] We are therefore obliged to have recourse to another explanation—namely, the decrease, and in part cessation, of the rainfall over the entire hydrographical basin of the river—in order to account for the decrease in volume.

The hypothesis of a former greater volume of the river has the support of Leith Adams, Zittel, Lyons, and others, and may therefore be considered as an accepted hypothesis; though it is not, as it seems to me, brought forward with sufficient prominence by writers

[1] It is near this place that the great Nile embankment is to be made.
[2] Quart. Journ. Geol. Soc. vol. xx. (1864) p. 15. The species were determined by the late S. P. Woodward, of the Natural History Museum.
[3] At Silsileh, where the Nubian Sandstone crosses the river, the solid rock was still not met with after boring to a depth of 20 to 22 metres (65 to 73 feet) below low Nile, 'Rep. Technical Commission,' p. 21 (1894).
[4] Report on 'Perennial Irrigation of Egypt,' 1894, p. 12.

on Egyptian geography, who have had generally other objects of investigation before their minds, but I should like to quote in this connexion the language of Prof. Zittel as follows:—

'Alle diese Thatsachen beweisen, dass der Nil einst ein weit mächtigerer und reissenderer Strom als heutzutage war, und dass die Gattung *Ætheria*, welche jetzt erst südlich von Assuan beginnt, früher weiter nach Norden verbreitet war.'[1]

Part IV.

8. The Pluvial Period.

When traversing, in 1883–84, the fine valleys of the Sinaitic Peninsula and Arabia Petræa, the bottoms of which, now dry, are composed of alluvial deposits, I came to the conclusion that at a former period, and under different climatic conditions, they constituted the channels of an extensive river-system draining into the Red Sea.[2] It is only at rare intervals that rain falls over this region, in the form of spasmodic thunderstorms of short duration, and they are quite insufficient to account for the formation of valleys, sometimes a mile or more in breadth and hundreds of feet in depth. The dry river-valleys which open into the Nile, chiefly along the eastern side, tell a similar tale. The streams which flowed along them, and by which they were excavated, have dried up and disappeared. The period during which this process of valley-erosion, of terrace formation, and of high floods went on may well be designated 'Pluvial'—extending from the Pliocene down through the post-Pliocene, and terminating with recent times. It is a term indicative of meteorological rather than geological conditions, though not unconnected with these.

Conclusion.

The conclusion to which we are driven from a consideration of the above phenomena is that the Nile has decreased in volume to a large extent, as compared with that of primeval times. It only remains to consider how and when this decrease has arisen.

(1) As regards the manner in which this change took place, there can be only one answer: by the drying up of its sources and tributaries owing to decrease in the rainfall. Throughout 1200 miles of its course, the river runs through a region well nigh rainless, where its waters are subject to a constant drain through evaporation; in consequence of which its volume at Khartum is considerably larger than it is at Cairo; and the only wonder is, when one contemplates the extent of this evaporation, especially during the

[1] 'Palæontographica,' vol. xxx. 1883, p. 137. Zittel founds this opinion mainly on the discoveries by Leith Adams of fluviatile shells in the terraces beyond the reach of the highest floods.

[2] 'Geology of Arabia Petræa, etc.' Mem. Palest. Expl. Fund, *passim*.

[3] Such as the Wadi Sennur, opposite Beni Suef; W. Tarfeh, north of Minieh; W. Siut, opposite the town of the same name; W. Gasmah, opposite Girgeh; W. Keneh, a valley with numerous branches, opposite Keneh; and W. Abu Wasail, below Luxor.

hotter months, that its waters ever reach the Mediterranean at all. That they do so is owing to the fact that it is during these months that the waters rise by reason of the Abyssinian floods. The numerous dry valleys which enter the Nile Valley in Middle and Upper Egypt and Nubia show that this region was once abundantly watered.

When we consider the enormous area of the hydrographical basin of the Nile, estimated at 1,100,000 square miles, we can understand how a slight climatic change in the direction of increased humidity and decreased temperature would cause an enormous expansion of volume of Egypt's great river. This is really what I believe took place, and it now remains to consider the period to which we should refer these altered conditions.

(2) During the Miocene period, when the primæval river was channelling out its bed, and when the land was relatively higher than at present as regards the surface of the Mediterranean, the climatic conditions may have been altogether different from those of the present day over the Nile Basin; but whether this was the case or not, we have good grounds for believing that during the subsequent Pliocene period, when Lower Egypt was submerged to a depth of over 200 feet, and the sea stretched up the Nile Valley for several hundred miles, the conditions were different from those of the present time. The increase of water surface must have been accompanied by increased humidity, and a lowering of temperature, compared with that of Miocene times. And when these Pliocene conditions gave place to those of the Pleistocene period the climatic conditions in the same direction must have been still further advanced.[1] The lowering of temperature over all the Europasian regions to the north must have greatly affected those we are now discussing. To what extent the annual mean temperature of the subtropical regions of Africa was lowered during the Glacial period of the temperate zone can scarcely be estimated with precision, but that the general effect was brought about cannot, as it seems to me, be contested. My own view is that in these regions the climatic conditions were similar to those of Europe at the present day, both as regards temperature and rainfall; and if such were even approximately the case, it is easy to account for the vastly greater volume of the Nile waters as compared with those which render Egypt not only a habitable but a fertile country. For this epoch I adopt the term first, I believe, suggested by Mr. Jameson for this part of the world namely, the Pluvial period.[2]

[1] Lyons considers that at this period (post-Pliocene) there was 'a considerable rainfall' over the area of the Libyan Desert though not excessive. Quart. Journ. Geol. Soc. vol. l (1894) p. 532. See also E. A. Floyer, *ibid.* vol. xlviii (1892) p. [illegible]

[2] Capt. Lyons has unintentionally misrepresented my meaning when he suggests that I have restricted the term 'Pluvial period' to that represented by the Glacial of Europe. On the contrary, I expressly regard it as extending from the Pliocene down to the close of the post-Pliocene, as will be seen on referring to my memoir on the 'Physical Geology of Arabia Petræa and Palestine,' Mem. Palest. Explor. Fund (1886), pp. 69, 113.

18. *On* CERTAIN GRANOPHYRES, MODIFIED *by the* INCORPORATION *of* GABBRO-FRAGMENTS, *in* STRATH (SKYE). By ALFRED HARKER, Esq., M.A., F.G.S., Fellow of St. John's College, Cambridge. (Communicated by permission of the Director-General of the Geological Survey. Read February 26th, 1896.)

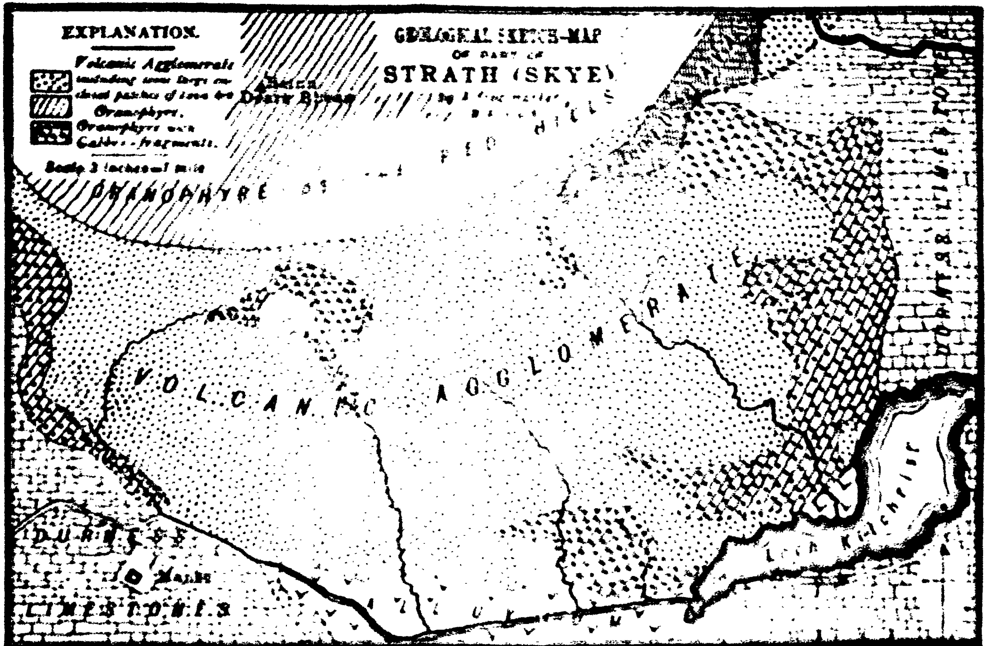
[PLATES XIII. & XIV.]

THE district of Strath in Skye, which has so often formed the subject of geological description, has been assigned to me to be mapped in detail for the Geological Survey; and while engaged in this duty, during the past summer and a portion of the autumn, I had occasion to study the complex series of eruptive rocks which extends from Loch Slapin on the west to the Sound of Scalpay and Broadford Bay on the east. Among the features of interest connected with these igneous rocks, special importance attaches to their relations one to another, and this subject has received due attention. The full details will be fitly deferred until the appearance of the official Memoirs; but, with the sanction of the Director-General, I now present to the Society the following brief account of certain minor intrusions of granophyre illustrating a peculiarity which, I believe, has not yet received notice.

The granophyres of Skye have been described, as a whole, by Macculloch, Oeynhausen and von Dechen, J. D. Forbes, Sir Archibald Geikie,[1] Prof. Zirkel, and Prof. Judd. Despite mineralogical and textural variations, these rocks have a general community of characters, which they share also with rocks of various ages in other regions. The examples to be described, however, present quite exceptional features, which seem to be worthy of examination. They form five distinct intrusions lying north and west of Loch Kilchrist and 2 or 3 miles south-west of Broadford (see Map). At this locality occurs a large tract of massive volcanic agglomerate, which has its own interest as marking, according to Sir A. Geikie,[2] the site of a large volcanic vent. It is within, and on the borders of, this agglomerate-tract that the intrusions are situated. In the surrounding district numerous other masses of granophyre occur. Immediately to the north is the large boss forming the Red Hills; to the south is another rising into Beinn-an-Dubhaich, while several smaller intrusions are perhaps to be regarded as offshoots from these large ones; but from all of these the peculiar rocks in question are at once picked out in the field as presenting marked differences from them.

[1] I follow Sir A. Geikie in grouping all the Tertiary acid rocks of this region under the collective name 'granophyre,' which is strictly applicable to most of them, although there are transitions both to the granitoid type on the one hand and to fine-textured 'quartz-felsites' on the other.

[2] Trans. Roy. Soc. Edinb. vol. xxxv. (1888) pp. 107-109.


EXPLANATION.
Volcanic Agglomerate
Granophyre.
STRATH (SKYE)
GRANOPHYRE
VOLCANIC AGGLOMERATE
LIMESTONES

Compared with what may be called the normal granophyres of the district, these rocks are darker and manifestly richer in the iron-bearing minerals. Examination shows, too, that they are decidedly denser: ten specimens gave specific gravities ranging from 2·56 to 2·73, with a mean of 2·66, while twenty specimens of the normal granophyres of the district gave from 2·51 to 2·66, with a mean of 2·58. Closer inspection often reveals a mottled appearance, due to the dark minerals tending to cluster in vaguely defined patches, and in places these patches become more distinct and are seen to represent enclosed fragments of some basic rock. In other respects, for example, in the prevalence of the micrographic structure, in the drusy character of the more coarsely textured type, etc., these rocks show a close correspondence with the normal granophyres of the district. It cannot, of course, be asserted that they agreed precisely with the latter as regards the composition of the original magma, but it will be shown that the differences which now exist are certainly due, at least in the main, to the taking up and partial dissolution by the acid magma of foreign rock-fragments of more basic composition.

It is to be observed that these peculiar granophyres do not occur as marginal modifications of, or as having any visible relation to, granophyres of the normal kind, but as independent intrusions. Moreover, the special characters of these rocks are distributed with considerable uniformity throughout each intrusion. Another point to be noticed is that the enclosed rock-fragments have not been derived from the rocks which border the intrusions as seen in outcrop. Excepting that the most easterly and the most westerly of the intrusions are in part bounded by limestone, the rock in contact is everywhere the volcanic agglomerate. The rock-fragments in the agglomerate are chiefly of sandstone and grit, probably Jurassic, and basalt similar to that of the bedded lavas of the district. The included fragments in the granophyre are in general of gabbro, which I have not detected in the agglomerate. They were therefore derived from some subterranean source, and, as we have seen, from such a depth as to allow of their becoming distributed with some regularity through the invading magma prior to the consolidation of the latter in its present surroundings.

The literature of foreign fragments enclosed in igneous rocks is voluminous, but it gives little information bearing on such a case as the present, where portions of a basic rock have been enveloped and attacked by an acid magma. Indeed, Zirkel[1] remarks that 'caustic' action is not known in the case of fragments enclosed in granites and syenites. The fullest account of such phenomena is that given by Prof. Sollas[2] in his description of the relations of the granite and gabbro of Barnavave in the district of Carlingford. This occurrence has obvious points in common with the one under discussion: some of the differences between the two will be brought out in the following pages. The modifications exhibited by the

[1] 'Lehrbuch der Petrographie,' 2nd ed. vol. i (1893) p. 593.
[2] Trans. Roy. Irish Acad. vol. xxx. pt. xx. (1894) pp. 477–512.

Carrock Fell granophyre near its contact with a highly basic gabbro have been described by the present writer,[1] but there the dissolution of the derived material has been much more complete, and the analogy with the present case is more remote.

The xenoliths[2] in our granophyres are, as a rule, less than an inch in diameter, and have ill-defined outlines. Those readily recognized and identified by the eye as distinct foreign fragments are not common. In the thin slices undestroyed xenoliths are not frequent (6704), but altered xenocrysts are universally found.

Most of this derived material has undoubtedly come from a gabbro, and from one closely comparable with the ordinary gabbros of the district, such as that which occupies a considerable tract to the north-east of the Red Hills. Of these gabbros, as seen *in situ*, a summary description will suffice. They consist essentially of felspar and augite. The felspar is usually a labradorite, often in idiomorphic crystals showing some zonary banding between crossed nicols. The augite is pale brown to almost colourless in thin slices. Instead of the true diallage structure, parallel to the orthopinacoid, it has usually a delicate striation[3] parallel to the basal plane, often emphasized by a more or less pronounced schiller-structure. This frequently affects only part of a crystal, and it imparts a deeper brown tint to the slice. A rhombic pyroxene is rarely met with in the gabbros of this district, though it occurs in some of the coarser rocks of the Cuillin Hills, farther west. Recognizable olivine is not common, although it may sometimes be concealed by secondary magnetite-dust, as remarked by Prof. Judd. Original magnetite often occurs, in shapeless grains or patches. Needles of apatite are met with, but by no means constantly.

The gabbro-debris in the granophyre is seen in the thin slices in different stages of dissolution, but is for the most part completely disintegrated by the caustic or solvent action of the acid magma on some of its minerals. Those constituents which resisted such action have been set free, and now figure as xenocrysts, either intact or more or less perfectly transformed into other substances. At the same time the material absorbed has modified the composition of the magma, in the general sense of rendering it less acid, and this is of course expressed in the products of the final consolidation of the granophyre. In order to present in systematic form the observations made, it will be convenient to begin by enquiring what has befallen each of the chief constituents of the gabbro.

[1] Quart. Journ. Geol. Soc. vol. li (1895) pp. 125-139.

[2] [For convenience I adopt Prof. Sollas's terms 'xenolith' for an enclosed foreign rock-fragment, and 'xenocryst' for an isolated crystal of foreign derivation.]

[3] [I follow Mr. Teall (Quart. Journ. Geol. Soc. vol. xl (1884) pp. 646, 647) in terming this structure simply a 'striation.' It does not appear to be a twin-lamellation, and I have not been able to satisfy myself as to its true nature. Mr. Teall regarded it, in the Whin Sill, as of secondary origin; but I have seen nothing leading to this conclusion in the gabbros of Skye, of Carrock Fell, of St. David's, etc., and its occurrence in 'xenocrysts' as detailed below would be difficult to reconcile with such a supposition.—March 12th, 1896.]

It is probable that the needles of apatite seen in most of the slices have been in part derived intact from destroyed gabbro-fragments, but this is not susceptible of decisive proof. Similar needles occur in the normal granophyres as well as in the gabbros of the district, and their rather capricious distribution in both rocks renders unsafe any argument founded on the relative amounts of the mineral in different slides.

It is the augite that affords the most conclusive proof of the extraneous origin of the xenocrysts, and this is due to the characteristic basal striation of the gabbro-augite, a feature not found in the augite of the normal granophyres. In the recognizable enclosed fragments of gabbro (6704)[1] the augite shows no change except a conversion to brownish-green, rather fibrous hornblende at the edge of the crystal, a transformation very common in the ordinary gabbros of the district (Pl. XIII. fig. 1). In the isolated xenocrysts the conversion to hornblende is usually far advanced, and in these rocks in general this mineral predominates over augite. It is yellowish to brownish-green or sometimes greenish-brown in colour, and of compact (as contrasted with fibrous) structure. Very often there is a core of unchanged augite with the basal striation that indicates its derivation from gabbro, and the traces of this structure are sometimes seen—even when the conversion to hornblende has been complete (Pl. XIII. fig. 3). Failing this evidence, the derivation of the hornblende can often be inferred from the irregular shape of its crystals, or from its enclosing abundant shapeless grains of magnetite. On the other hand, there is usually some hornblende presenting the crystal outlines proper to that mineral, and this must certainly have crystallized out from the modified granophyre-magma (Pl. XIII. figs. 4, 5). In some slides it is very plentiful. It does not differ materially in colour and pleochroism from the pseudomorphic hornblende. It may be remarked that when the latter encloses a core of unchanged augite the two minerals have the usual crystallographic relation, the *b* and *c* axes being common to both: in a clinopinacoidal section the extinction-angle of the augite is 39°, and of the hornblende 18°, on the same side of the vertical (2674). In addition to the augite plainly derived from gabbro, several of the slides contain rather rounded grains of augite showing neither basal striation nor partial conversion to hornblende. Unless these be relics of vanished xenoliths of basalt, they are probably to be regarded as having crystallized out directly from the modified granophyre-magma (Pl. XIII. fig. 1). This would not be remarkable, for augite is widely distributed in the normal granophyres of the district, where it often occurs side by side with original hornblende. Since, however, non-striated augite is found in many of the gabbros, the absence of this structure cannot in itself be regarded as conclusive.

At Barnavave the xenocrysts of diallage are described by Prof. Sollas as showing three different lines of alteration, the characteristic products being respectively granular augite, biotite, and green horn-

[1] The numbers between parentheses are those of the slides in the collections of the Geological Survey.

blende, with magnetite as a concomitant of each. Only the last of these three is clearly represented in the present case: newly-formed augite has been produced only indirectly by later secretion from the modified magma, and biotite has not been observed. At Carrock Fell the derived augite-crystals have been completely absorbed by the magma, and subsequent crystallization has given rise to new augite with hornblende and biotite.

Two of the slides (2674, 6703) afford evidence of the occurrence of xenocrysts of enstatite and hypersthene. There is a partial conversion to hornblende at the margin, while the interior is serpentinized or more rarely unaltered (Pl. XIV, fig. 7).

Occasionally pseudomorphs after olivine, apparently of 'pilitic' amphibole, are seen enclosed in the relics of striated augite (6704), or isolated in the granophyre-matrix (6703). There is no decisive criterion to determine whether these latter have come from the gabbro or from destroyed basalt.

Magnetite grains of irregular shape are embedded in many of the augite xenocrysts and the hornblende-pseudomorphs after them, and these do not differ from the grains in the original gabbro. Most of the abundant magnetite in the slices is, however, of a different kind, building perfect or imperfect octahedra. Though partly representing in substance iron ore absorbed from gabbro-debris, it is evidently a new crystallization from the modified granophyre magma. At Carrock Fell the iron ore from the gabbro has been mostly, but not entirely absorbed; its partial survival may be due to its extraordinary amount and its highly titaniferous nature.

Distinct xenocrysts of gabbro-felspar are rare in the specimens sliced, but they are occasionally found, especially in the neighbourhood of actual gabbro-xenoliths. One suitably oriented crystal gave extinction angles 35° and 36° in alternate lamellæ, and is presumably labradorite like the common felspar in the gabbros of the district. It has a marginal intergrowth of a more acid felspar, and, like the felspar-phenocrysts in all these granophyres, has served as nucleus for a growth of micropegmatite (6701). It is clear that most of the felspar of the enclosed gabbro-fragments has been completely absorbed by the enveloping magma. The result is seen in a great preponderance of soda-lime over potash-felspar in the rock as finally consolidated, compared with the normal granophyres of the district. This dominant felspar seems, however, to be chiefly the usual oligoclase, with quite low extinction-angles. At Barnavave xenocrysts of felspar (bytownite) seem to be common, though they are described as showing corrosion and other signs of change.

Apart from the peculiarities described, the rocks here dealt with present a general similarity to the normal granophyres. There are, however, one or two special points worth noting. Several writers, in describing the phenomena of xenoliths of acid rocks in basalts and diabases, have remarked a tendency to the formation of hollow spaces, usually filled by later products. Indications of the same tendency are not wanting in the present converse case, though

the circumstances are different. In one example are seen ring-like aggregates, about $\frac{1}{10}$ inch in diameter, of hornblende-crystals, surrounding areas of clear quartz (6705, Pl. XIII. fig. 6). Quartz is frequently seen moulded upon hornblende-crystals, and, in several slides, penetrated by actinolitic needles (Pl. XIII. fig. 5). Such patches of quartz are quite different from the quasi-porphyritic grains common in the granophyres, and they seem to be of late formation—not necessarily secondary in the usual sense. They probably occupy what have once been vacant spaces formed in connexion with the destruction of xenoliths, and are quite distinct from druses. The latter are also found here just as in the normal granophyres, and are commonly filled by calcite and quartz (6707, Pl. XIV. fig. 8). In places it can be seen that the calcite-crystals project into the quartz, which again indicates that some of the latter mineral belongs to a very late stage in the history of the rock.

In addition to the relics of gabbro in these granophyres there are occasional traces of inclusions of other rocks. In particular there are granular aggregates consisting largely of hornblende and magnetite and presenting angular outlines to the surrounding matrix (6709, Pl. XIV. fig. 10). These probably represent xenoliths of basalt in an advanced stage of dissolution. At junctions of basalt and granophyre in other parts of Skye, as well as in Rum, Mull, and Ardnamurchan, detached fragments of basalt in the granophyre can be traced down to quite similar aggregates. In some cases the ferro-magnesian mineral produced is augite; in other cases, as here, it is hornblende. The greater part of the rocks now described contain no trace of foreign fragments other than those of gabbro.

There are, however, certain fine-textured portions of these granophyre-masses to which allusion has not yet been made, and the xenoliths in these are of a different character. The rocks occur on the margin of an intrusion or as a limb extending from the main body, and it is not easy to decide whether these and the more usual coarse type represent parts of a single intrusion. The granophyric structure is absent or scarcely developed in these fine-grained rocks, and one example shows strong fluxion (Pl. XIV. fig. 12). The enclosed fragments are very distinctly seen in hand specimens, are subangular to rounded in shape, and are chiefly of dark compact lava, usually not more than $\frac{1}{4}$ inch in diameter. One slide shows recognizable pieces of basalt, partly vesicular, of microlitic andesite, and of a quartzose grit (6701, Pl. XIV. fig. 11). Another shows only basalts, one with porphyritic felspars (6702). Gabbro has not been identified, and the fragments noticed are all such as might be obtained from the agglomerate through which the intrusions have broken. They are in no case very highly altered, and, though their rounded form points to a certain amount of absorption by the magma, the latter has clearly not been very considerably enriched in basic constituents. In all these points these rocks contrast with the coarser granophyres described above.

The fine-textured rocks, with their evidence of comparatively rapid chilling, presumably represent the earliest irruptions of the acid magma. The marked difference between them and the coarser

granophyres seems to point to a distinct separation between them in respect of time and of the circumstances attending intrusion, and the contrast between the xenoliths of the two types decidedly enforces this reasoning. The portion of the acid magma first intruded appears to have merely enclosed fragments derived from the bounding walls, as many other igneous rocks have done in this and other districts. The main body of the granophyre-magma, which followed perhaps after some interval of time, has taken up foreign material amounting to fully $\frac{1}{4}$ of its own bulk, derived, not from the bordering rocks, but from a gabbro probably at a considerable depth beneath. Herein, too, this latter case differs from the examples already cited from other districts. At Barnavave, where the evidence seems to be singularly complete, the phenomenon is essentially a 'contact' one. At Carrock Fell, owing to special circumstances upon which I have remarked elsewhere, the dissolution of the derived fragments has proceeded much farther than in the Irish example, but the broad relations are the same. The modification of the granophyre is confined to the neighbourhood of its contact with the gabbro, and disappears rapidly as we recede from that contact. In the instance now described in the Strath district, on the other hand, the abundant foreign material has been taken up prior to the intrusion of the magma into its present surroundings; has been distributed with some approach to uniformity prior to or during the intrusion; and, except for the relics described above, has then been absorbed into the granophyre-magma. The whole mass of each intrusion, excluding the fine-textured non-granophyric portions, has the same general characters throughout.

A question of general interest naturally arises from a consideration of this case. If the caustic action of the acid magma had been from any cause more energetic, and had sufficed to destroy the relics of gabbro as completely as has been effected at Carrock Fell, it would have been impossible (without careful and specially directed search) to detect any evidence of the incorporation of foreign material. Is, then, this factor an important one to be taken into account in discussing the origin of igneous rocks in general? Prof. Sollas, Dr. Johnston-Lavis,[1] and some other geologists would probably answer this question in the affirmative: I refrain from expressing any opinion.[2] The facts detailed above admit of obvious application to the problem; but it may be urged on the other hand that, were complete absorption of xenoliths to modify the composition of a rock-magma a frequent occurrence, cases of incomplete absorption such as that here described should be more common than they appear to be.

[1] Geol. Mag. 1894, pp. 47-48, 252-254; 'Natural Science,' vol. iv. (1894) pp. 134-140. Comp. A. von Lasaulx, Neues Jahrb. 1870, p. 713.

[2] Prof. Brögger has recently stated with much cogency the argument against the hypotheses of Kjerulf, Michel Lévy, and others, which suppose that granite-intrusions have in general 'assimilated' large portions of the neighbouring solid rocks. See 'Die Eruptivgesteine des Kristianiagebietes,' pt. ii. pp. 116, et seqq. Videnskabsselskabets Skrifter, I. Mathematisk-naturv. Klasse, 1895, No. 7.

EXPLANATION OF PLATES XIII. & XIV.

[The numbers in brackets are those of the figured slides in the collection of the Geological Survey at the Jermyn Street Museum.]

Plate XIII.

Fig. 1. [6704.] × 20. Granophyre showing native and foreign augites. To the right of the magnetite in the centre are several granules of augite proper to the granophyre; to the left of the figure is a gabbro-xenolith but little altered. In this the pale, well-cleaved augite forms ophitic plates enclosing the felspar, and the only alteration is a little marginal conversion into hornblende. The basal striation is not seen here. See p. 324.

Fig. 2. [6705.] × 40. Granophyre showing xenocrysts of augite derived from gabbro. This is proved by their retaining the basal striation and schillerization, which is combined with the ordinary orthopinacoidal twinning to give the 'herring-bone' structure. See p. 324.

Fig. 3. [6709.] × 20. Similar augite-xenocrysts converted into hornblende, but still retaining the basal schillerization. See p. 324.

Fig. 4. [6706.] × 150. Granophyre showing native hornblende. This is proved by its crystal-form. See p. 324.

Fig. 5. [6708.] × 150. Also showing idiomorphic hornblende and, in addition, actinolitic needles embedded in clear quartz. See p. 326.

Fig. 6. [6705.] × 20. Ring of hornblende-crystals surrounding an area of clear quartz, to which they present idiomorphic outlines. See p. 326.

Plate XIV.

Fig. 7. [2674.] × 20, polarized light, crossed nicols. Granophyre containing a xenocryst of enstatite, probably derived from gabbro. The interior of the crystal is converted into the usual serpentinous pseudomorph, but the margin is replaced by fibrous hornblende. Towards its right-hand end the crystal encloses two or three patches of compact hornblende, probably an original intergrowth. See p. 325.

Fig. 8. [6707.] × 20, polarized light, crossed nicols. Granophyre with druse, occupied by quartz and calcite; a feature common to the ordinary coarse granophyres of the district. See p. 327.

Fig. 9. [6707.] × 20; polarized light, crossed nicols. Granophyre showing delicate micrographic intergrowths of felspar and quartz. This also is characteristic of the ordinary granophyres of the district, from which the rocks described (when not showing actual relics of foreign material) differ only in their greater richness in the coloured minerals.

Fig. 10. [6700.] × 20, polarized light, crossed nicols. An angular patch rich in hornblende and magnetite, probably an altered xenolith of basalt. See p. 328.

Fig. 11. [6701.] × 20; outlines drawn by polarized light, crossed nicols. Fine-textured variety of granophyre (but non-granophyric), containing various xenoliths. In the lower part of the figure are fragments of altered glassy basalt; above and to the right is a piece of quartzose grit, and to the left of this a felspar-xenocryst. See p. 326.

Fig. 12. [6702.] × 10. Another fine-textured example, showing flow-structure. There are numerous xenoliths, chiefly of basalt, the smaller ones lenticular in form and arranged along the stream-lines. See p. 330.

Discussion.

Sir Archibald Geikie referred to the fact that Mr. Harker had been appointed to the Geological Survey only last spring, and that the present paper was the result of his first season's work. The region described by the Author was exceedingly familiar to the speaker, and he rejoiced to welcome this application of modern petrographical methods to its investigation. The paper had a double value. In the first place, it was important in regard to the local geology of the Western Isles, for it demonstrated by new evidence the posteriority of the granophyres to the gabbros; and in the second place, it had a suggestive bearing upon questions of theoretical interest regarding the possible modification of eruptive rocks by the incorporation of foreign material into their substance. He felt sure that farther and even more extensive evidence of the same kind would be encountered in other parts of the same region of Skye. The inspection of Mr. Harker's specimens reminded the speaker of some puzzling rocks on the flanks of Glamich and other hills, which many years ago he saw to be too acid for the gabbros and too basic for the granophyres. He looked forward to having these and many other problems solved by the continuation of the same patient and skilled observation as had been shown in the investigations described in the present paper.

Lieut.-Gen. M'Mahon said that he had listened to Mr. Harker with great interest, and looked forward with pleasure to studying the details of the paper. He was quite prepared to accept the Author's conclusions, because he had found augite in the granite of the Chor Mountain, North-western Himalayas, and attributed its presence to the digestion of fragments of basic rocks caught up by the granite. Mr. R. D. Oldham, Superintendent of the Geological Survey of India, had also found hornblende locally abundant in the granite of one part of the Chor, and attributed it to the granite having 'dissolved and absorbed the rocks whose position it occupies.' The presence of magnetite, however, stood on a different footing. It was rather abundant throughout the granite of the North-western Himalayas; but if the Author could show that its presence in the granophyre of Skye was due to the assimilation of gabbro, the fact would be very interesting.

Prof. Miers called attention to a large mass of coarsely-granular basic rock which exists in the granophyre on the western flank of Marsco, and may be distinguished from the summit of Sgurr-na-Gillean as a dark band about 20 feet in breadth, traversing the face of the hill in a vertical direction.

Mr. W. W. Watts pointed out that Prof. Sollas's researches at Barnavave had prepared the Society for this paper. He alluded to the association of gabbro and granophyre at so many places, including Radnor and Carrock Fell, and pointed out that the Whin Sill at Caldron Snout passed into a rock which was practically a gabbro embedded in granophyre.

Dr. Du Riche Preller said that already on a former occasion

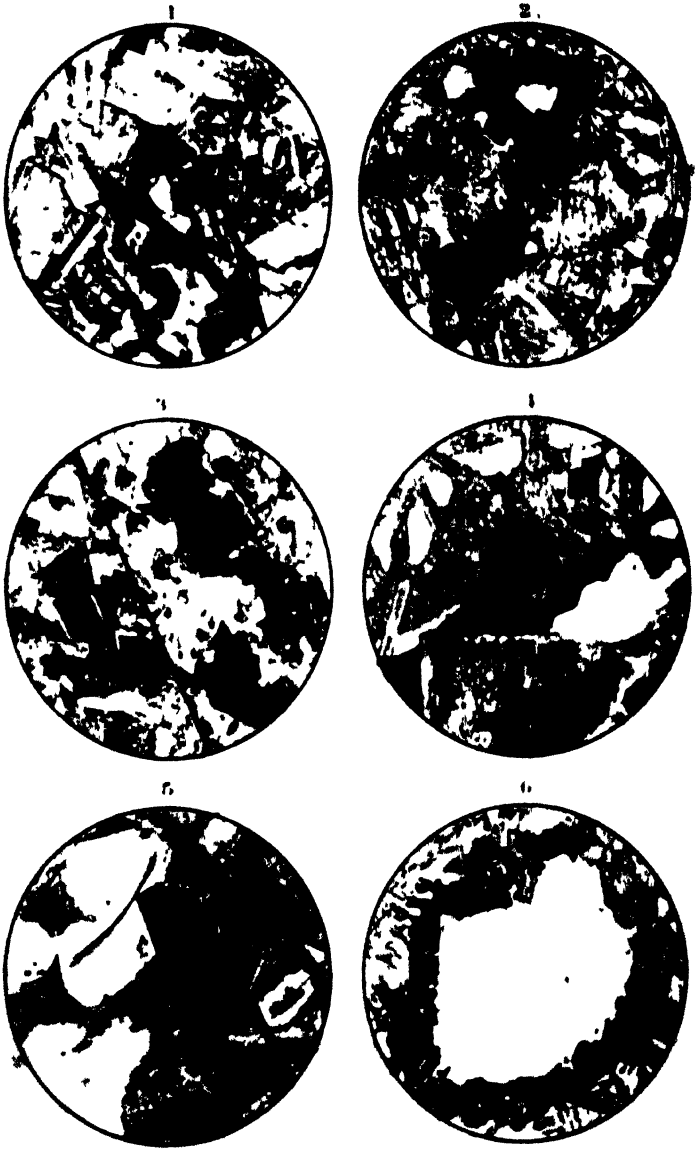
he had pointed out that Sir Archibald Geikie's conclusions with respect to the granophyre of the Western Islands of Scotland being intrusive into the gabbro, and therefore younger than the latter, were strikingly confirmed by the precisely similar phenomenon in the Island of Elba, where the Tertiary granite traversed the gabbro, diabase, and serpentine dykes. Mr. Harker had now shown the same phenomenon to exist also in Skye, and the speaker therefore wished to emphasize the analogy of Elba, the more so as Gen. M'Mahon had brought forward similar evidence with reference to the Himalayas.

Mr. Barrow drew attention to the strong contrast between the evidence adduced by the Author to show actual absorption of part of these inclusions, and that published some time ago in his and Mr. Marr's work on the metamorphic aureole surrounding the Shap Granite. In the latter case, the Authors selected the amygdules in certain altered igneous rocks, and produced exceptionally clear evidence of the extremely limited migration of material that accompanied the development of new minerals in these bodies. Experience has shown that some of our best data are obtained in searching for the cause of such widely differing results. At present the evidence seems to suggest that the 'initial depth temperature' may be one of the chief factors in determining the amount of change produced.

Mr. Rutley asked for further information regarding the geological structure of the area represented in the diagram. It was suggestive of proximity to a centre of eruption, and the irregular character of the patches mapped as gabbro-bearing granophyre, and their association with volcanic agglomerates and bedded lavas, favoured this belief. Cases such as this, of the absorption of fragments of a basic rock by an acid one, were, he thought, of comparatively rare occurrence. The reverse was more frequently the case. The exposures, described as dykes, might possibly be portions of buttress-dykes cutting irregularly through the agglomerates. The paper dealt with several points of great interest.

The President also spoke.

The Author briefly replied, thanking the speakers for their appreciation and criticism. Though the phenomena of incorporation of basic material by an acid magma appeared to be uncommon, at least on such a scale as in the examples described, the converse case of acid rocks absorbed into basic was illustrated by very many dykes in the Skye district. A considerable difference in acidity between the absorbed and the absorbing rock seemed to be as essential a factor in the process as that of temperature: hence the absorption of gabbros by granophyres observed in several districts. The peculiar intrusions described were possibly somewhat younger than the normal granophyres of Skye; but wherever these latter were seen in junction with gabbros in the area as yet mapped by the Author, the same relation, namely, the acid intrusion succeeding the basic, was invariably verified.



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GRANOPHYRES WITH FOREIGN INCLUSIONS.

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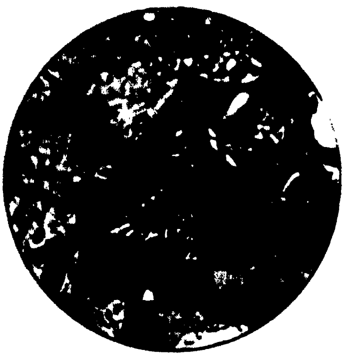

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GRANOPHYRES WITH FOREIGN INCLUSIONS

19. *The* Tertiary Basalt-plateaux *of* North-western Europe. By Sir Archibald Geikie, D.Sc., LL.D., F.R.S. (Read December 18th, 1895.)

[Plates XV.–XIX.]

Contents.

Introduction.

Since the publication, seven years ago, of my memoir on 'The History of Volcanic Action during the Tertiary Period in the British Isles,'[1] I have continued the investigation of this subject. My researches in this interval have included a re-examination of various tracts in Mull, Rum, Raasay, and Skye; numerous traverses in the last-named island, especially over areas which had not been previously described by any geologist; a detailed survey of Canna and its adjacent islets; an exploration of the Shiant Isles and other insular outliers of the Tertiary sills, and a visit to St. Kilda for the purpose of accurately determining the relations of its two great groups of igneous rocks. In two successive years I have prolonged my excursions into the Faroe Islands, where the phenomena of our basaltic plateaux are reproduced on a colossal scale, and where the numerous fjords and sounds have laid bare the most stupendous range of geological sections. This extended series of observations, while entirely confirming the main conclusions announced in my former memoir, has furnished many fresh and important illustrations of phenomena already described, and some new and interesting additions to our knowledge of the volcanic history of Tertiary time over the North-west of Europe. I now lay before the Society an outline of the chief results which have thus been obtained.[2]

[1] Trans. Roy. Soc. Edin. vol. xxxv (1888) pp. 21–184.

[2] It is a pleasure to acknowledge the great assistance which has been kindly afforded to me in these researches. I am specially indebted to my friend Mr. Henry Evans, who, by placing his steam-yacht *Aster* at my disposal, enabled me to visit many localities among the Inner Hebrides and outer islands which are not easily accessible, and to make acquaintance with the whole group of the Faroe Islands. His brother, Col. John Evans, photographed for me

As the literature of the subject was fully summarized in my former memoir, it need not be further referred to here. Such more recent papers as bear on any of the localities which I shall have to describe, or on any of the questions I shall discuss, will be cited as the occasion arises.

I. The Plateau-Lavas.

Every tourist who has sailed along the cliffs of Antrim, Mull, Skye, or the Faroe Islands is familiar with the singular terraced structure of the great volcanic escarpments which stretch as mural precipices along these picturesque shores. Successive sheets of lava, either horizontal or only gently inclined, rise above each other from base to summit of these walls, as parallel bars of brown rock with intervening strips of bright green grassy slope.

The geologist who for the first time visits these coast-lines is impressed by the persistence of the same lithological characters giving rise to the same topographical features. He soon realizes that the plateaux, so impressively truncated by the great escarpments that spring from the edge of the sea, are built up essentially of dark lavas,—basalts, dolerites, and andesites,—and that fragmental volcanic accompaniments, though here and there well developed, play on the whole a quite insignificant part in the structure and composition of those thick piles of volcanic material. Closer examination in the field enables him to ascertain that, regarded as rock-masses, the lavas include four distinct types:—

(1) Thick, massive, prismatic or rudely-jointed sheets, rather more coarsely crystalline and obviously more durable than the other types—inasmuch as they project in tabular ledges and tend to retain perpendicular faces, owing to the falling away of slices of the rock along the lines of vertical joint. Many rocks of this type are undoubtedly intrusive sheets, and as such will be further referred to in a later part of this paper. But the type includes also true superficial lavas which show the characteristic slaggy or vesicular bands at their upper and lower surfaces. The mere presence of such bands may not be enough, indeed, absolutely to establish that the rock possessing them flowed at the surface as a lava, for they are occasionally, though it must be confessed rarely, exhibited by true sills. But the rough scoriaceous top of a lava stream, the presence of fragments of this surface in the overlying tuff, or wrapped round by the next succeeding lava sufficiently attest the true superficial outflow of the mass.

(2) Slaggy or amygdaloidal lavas without any regular jointed structure, but often with roughly scoriform upper and under layers, and tending to decay into brown earthy debris. Some of the upper

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many points of geological interest met with in our cruises. The pleasant hospitality of Mr. Thom, the proprietor of Canna, enabled me to survey in great detail on the 6-inch map of the Ordnance Survey the deeply interesting geology of his island-home, and to revisit Hyskeir, while Miss Thom took photographs for me of some of the more striking geological features of Canna and Sanday.

surfaces of such sheets among the Tertiary basalt-plateaux must have resembled the so-called 'Aa' of the Sandwich Islands. A striking example of the structure may be noticed at Camas Tharbernish, on the northern coast of the island of Canna. There the hummocks on the upper surface of a slaggy basalt measure about 15 feet in breadth, and rise about 3 feet above the hollows between them like a succession of waves (see fig. 1, p. 334). The steam-holes are disposed in a general direction parallel to the strike of the hummocks.

Great variety obtains in the size and shape of the vesicles. Huge cavities a foot or more in diameter may occasionally be found, and from such an extreme every gradation may be traced down to minute pore-like vacuoles that can hardly be made out even with a strong lens. In regard to the deformation of the vesicles, it is a familiar general rule that they have been drawn out in the direction of the flow of the original lava. Occasionally this elongation has advanced so far that the cavities have become straight, narrow pipes, several inches long, and only an eighth of an inch or so in diameter. A number of such pipes, arranged parallel to each other, resembles a row of worm-burrows. Remarkable illustrations of such extreme mechanical deformation by the movement of a still molten rock may be collected in Mull and Skye.[1]

It is a common belief that the filling in of the steam-cavities has taken place long subsequent to the volcanic period by the slow percolation of meteoric water through the rocks. I believe, however, that at least in some cases, if not in all, the conversion of the vesicular lavas into amygdaloids was effected during the volcanic period. Thus it can be shown that the basalts which have been disrupted by the gabbros were already amygdaloidal before these basic intrusions disturbed them, for the kernels of calcite, zeolite, etc., have shared in the general metamorphism induced in the enclosing rock. Again, the blocks of amygdaloid contained in the agglomerates of the volcanic series are in every respect like the amygdaloidal lavas of the plateaux. It would thus seem that the infilling of the cavities with mineral secretions was not merely a long secular process of infiltration from the cool atmosphere, but was more rapidly completed by the operation of warmer water, either supplied from volcanic sources or heated by the still high temperature of the cellular lavas into which it descended from the surface.[2]

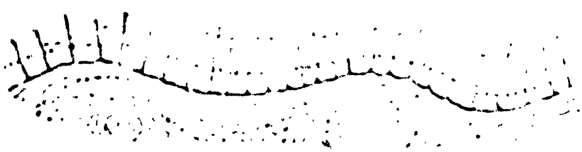
[1] Some examples have been deposited by me in the Museum of Practical Geology, Jermyn Street, in the case illustrating rock-structures. The elongation of the vesicles into annelid-like tubes may be observed among the stones in the volcanic agglomerates.

[2] Messrs. Harker and Marr have demonstrated that the Lower Silurian vesicular lavas of the Lake District had already become amygdaloids before the uprise of the Shap Granite, Quart. Journ. Geol. Soc. vol. xlix. 1893. J. D. Dana, originally an advocate of infiltration from above, subsequently supported the view here adopted, that the kernels of amygdaloids were filled in by the action of moisture within the rocks during the time of cooling (Am. Journ. Sci. ser. 3, vol. xx. 1880, p. 331).

Except in the elongation of the vesicles in one general direction, the amygdaloidal basalts seldom display any distinct trace of flow-structure. Occasionally, however, a striking exhibition of this structure may be seen among them. Thus at the top of the Dun Can, the highest summit of the island of Raasay, a small outlier of the plateau-lavas is capped with a black olivine-basalt, having a strongly-pronounced vesicular structure, wherein the cavities are filled with zeolites. The weathered faces of this rock show rudely parallel, puckered, and broken lines that mark the layers of devitrification in the original flowing lava.

(3) Prismatic or columnar basalts, which, as at the Giant's Causeway and Staffa, have long attracted notice as one of the most notable topographical elements in the structure of the plateaux. Though generally rather compact, becoming indeed dense, almost vitreous rocks in some sheets, they are often more or less cellular throughout, and highly slaggy along their upper and under surfaces. In some cases, as in that of a prismatic sheet which overlies the rough scoriaceous lava of Camas Tharbernish just referred to, the rows of vesicles are disposed in lines parallel to the under surface of the sheet (fig. 1).

Fig. 1.—*Section of scoriaceous and prismatic basalts. Camas Tharbernish, northern shore of Canna Island.*



As I have already remarked with regard to the massive, rudely-jointed sheets, many of the most perfectly columnar rocks of the plateaux are not superficial lavas, but intrusive sills, bosses or dykes. Conspicuous examples of the sills are displayed on the coast of Trotternish in Skye, of the bosses and dykes at the eastern end of Canna. To these further reference will be made in the sequel. It is not always possible to be certain that columnar sheets which are regularly intercalated among the undoubted lavas of the volcanic series may not be really intrusive. In some instances, indeed, we can demonstrate that they are so, when, after continuing perfectly parallel with the lavas above and below them, they eventually break across them. One of the most remarkable examples of this feature is supplied by the great sill of the south-west of Stromo in the Faroe Islands, of which I shall give some account in a subsequent section of this paper (figs. 9, 24, & 25, pp. 345, 380, 381).

(4) Banded or stratiform lavas, consisting of successive parallel layers or bands which weather into projecting ribs and flutings. The deceptive resemblance to sedimentary rocks thus produced

has no doubt frequently led to these lavas being mistaken for tuffs. As I have recently found them to be much more plentiful than I had supposed, a more detailed description of them seems to be required.

The banded character arises from marked distinctions in the texture of different layers of a lava-sheet. In some cases these distinctions arise from differences in the size of the crystals or in the disposition of the component minerals of the rock; in others, from the varying number and size of the vesicles, which may be large or abundantly crowded together in some layers, and small or only sparsely developed in others. The structure thus points to original conditions of the lava at the time of its emission, and may be regarded as, to some extent, a kind of flow-structure on a large scale.

Where the banding is due to differences of crystalline texture, the constituent felspars, augites, and iron-ores may be seen even with the naked eye as well defined minerals along the prominent surfaces of the harder ribs, while the broader intervening flutings of finer material show the same minerals in minuter forms. The alternating layers of coarser and finer crystallization lie, on the whole, parallel with the upper and under surfaces of the sheets in which they occur. But they likewise undulate like the streaky lines in ordinary flow-structure.

Banded structure of this type may be seen well developed in the lower parts of the basalt plateaux throughout the Inner Hebrides and the Faroe Islands. A specimen taken from the western end of the island of Sanday, near Canna, which showed the structure by a conspicuous parallel fluting on weathered surfaces, was sliced for microscopical examination. My colleague, Mr. Alfred Harker, to whom I am indebted for the notes on the microscopic characters of rocks described in the present paper, has been kind enough to supply me with the following observations regarding this slice.

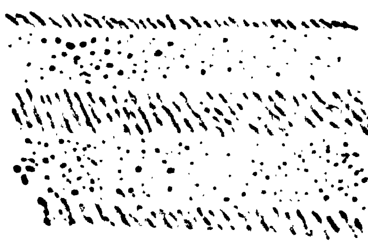
'In the slice [illegible][1] the banding becomes less conspicuous under the microscope. The rock is of basaltic composition, and, with reference to its micro-structure, might be styled a fine grained olivine-diabase or olivine-dolerite in some parts of the slice, an olivine-basalt in others. It consists of abundant grains of olivine, imperfect octahedra and shapeless granules of magnetite, little simple or twinned prisms of labradorite, and a pale brown augite. The last-named mineral is always the latest product of consolidation, but it varies in habit, being sometimes in ophitic patches moulded upon or enclosing the other minerals, sometimes in small granules occupying the interstices between the felspars and other crystals. The ophitic habit predominates in the slice, while the granulitic comes in especially along certain bands. If the former be taken as indicative of tranquil conditions, the latter of a certain amount of movement in the rock during the latest stages of its consolidation, the banding, though not strictly a flow-structure, may be ascribed

[1] The figures within square brackets throughout this paper refer to the numbers of the microscopic slides in the Geological Survey (Scotland) collection, where I have deposited all those prepared from my specimens.

in some degree to a flowing movement of the nearly solidified rock. There is, however, more than this merely structural difference between the several bands. They differ to some extent in the relative proportions of the minerals, especially of olivine and augite: which points to a considerable flowing movement at an early stage in a magma which was initially not homogeneous.'

Where the banding arises from the distribution of the vesicles, somewhat similar weathered surfaces are produced. In some instances, while the basalt is throughout finely cellular, interposed parallel bands of harder, rather finer-grained and less thoroughly vesicular characters serve to give the stratified appearance. Instances may be observed where the vesicles have been crowded together in certain bands, which consequently weather out differently from the layers above and below them. An excellent illustration of this arrangement occurs in the lowest lava but one of the largest of the three picturesque stacks known as Macleod's Maidens, on the western coast of Skye. This lava is thoroughly amygdaloidal, but the vesicles are specially crowded together in certain parallel bands from 1 to 3 or 4 inches thick. Some of these layers lie close to each other, while elsewhere there may be a band of more close-grained, less vesicular material between them. But the most singular feature of the rock is to be seen in the shape and position of the vesicles that are crowded together in the cellular bands. Instead of being drawn out into flattened forms in the general direction of banding, they are placed together at high angles. Each layer remains parallel to the general bedding, but its vesicles are steeply inclined in one direction, which doubtless indicates the flow of the still unconsolidated lava. Weathering along these bands, the lava might easily be mistaken at a little distance for a tuff or other stratified intercalation.[1]

Fig. 2.—*Banded amygdaloidal basalt showing layers of elongated and steeply inclined vesicles. Macleod's Maidens, Skye.*



Banded lavas possessing the characters now described are of frequent occurrence among the Inner Hebrides. Many striking examples of them may be seen along the western coast of Skye. Still more abundant in Faroe, they form one of the most conspicuous features in the geology of that group of islands. Along the whole of its western seaboard, on island after island, they are particularly prominent in the lower parts of the precipices, while the upper parts consist largely of amorphous or prismatic sheets. So much do they resemble stratified rocks that it was not until I had landed at

[1] This elongation of vesicles more or less perpendicular to the general bedding may be noticed sometimes even in sills, as will be shown farther on.

various points that I could satisfy myself that they are really banded lavas.[1]

On a first inspection any one of the great basalt-precipices seems to consist of regularly persistent sheets, which are continued from headland to headland, like strata of sandstone or limestone. I have dwelt on the deceptive nature of this apparent continuity, and have shown that when more closely examined these cliffs contain many proofs that, while the general bedding of the basalts is prolonged with much regularity, individual sheets may be seen to die out or to begin. I have insisted that these cessations do not occur in any general direction, that they furnish no evidence of any great central vents from which the lavas proceeded, but that on the contrary they show the eruptions to have probably taken place from many scattered vents and in every direction.

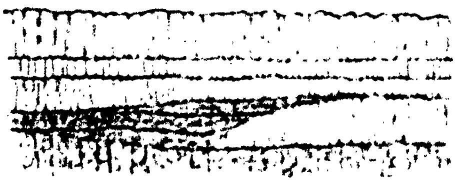
My recent journeys have furnished many additional proofs of the truth of this generalization. Closer scrutiny of the western cliffs of Skye last year, and again this summer, has brought to light numerous examples of the gradual or rapid disappearance of lava-beds, now in one direction, now in another. I may especially cite the great headland south of Talisker Bay, which reaches a height of 400 feet, and where, in the pile of nearly horizontal sheets, two beds may be seen to die out, one towards the north, the other towards the south. Farther north, in the cliff of the Hoe of Duirinish, 750 feet high, a similar structure presents itself. Owing to their greater exposure of bare rock, the sea-walls of the Faroe Islands furnish even more striking examples of discontinuity. On the western side of Sudero, lenticular beds of basalt form a conspicuous feature in the precipices that stretch northward from the highest headland. On Stromo the same structure occurs. Similar features arrest the attention on the precipices of Sando, where, though at first sight the basalts seem to be regular and continuous, a nearer view of them reveals such sections as that shown in fig. 3, p. 338, where a group of sheets rapidly dies out towards the north against a thicker band that thins away in the opposite direction. Farther north we come upon other examples in the range of low cliffs between Kirkebonaes and Thorshaven, and more impressive still in the rugged precipices that face the Atlantic on the western front of Hesto (fig. 4, p. 338), where the disappearance is in a northerly direction.

But it is in the northern part of the Faroes, where the basalt-plateau has been so deeply trenched by parallel fjords as to be broken up into a group of long, narrow, lofty, and precipitous insular ridges, that the really local and non-persistent character of

[1] It is not necessary to give here a synopsis of the geological literature of the Faroe Islands. I may, however, refer to some recent papers, particularly to one by Prof. James Geikie (Trans. Roy. Soc. Edin. vol. xxx (1880) p. 217); one by Prof. A. Helland (Dansk Geografisk Tidskr. 1881); R. Bréon, 'Notes pour servir à l'Étude de la Géologie de l'Islande et des Iles Færoe,' 1884, and one by Mr. J. Lomas, Proc. Geol. Soc. Liverpool, vol. vii (1895) p. 292. Various writers have treated of the petrography, particularly A. Osann, Neues Jahrb. 1884, vol. i. p. 45, and Bréon. Banded lavas are noticed by J. Geikie, op. cit.

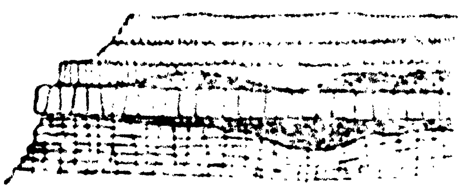
the lavas can best be seen. The eastern cliffs of Svinö present admirable examples, where in the same vertical wall of rock some of the basalts die out to the south, others to the north, while occasionally a shorter sheet may be seen to disappear in both directions as if it were the end of a stream that flowed at right angles to the others (fig. 5, below).

Fig. 3.—*Dying out of lava-beds, eastern side of Sandö, Faroe Isles.*



The islands of Kalsö and Kunö display the most impressive scenery of the plateau-basalts of Faroe. In these northern climes vegetation spreads less widely over rock and slope than it does in

Fig. 4.—*Lenticular lavas, western front of Hesto, Faroe Isles.*



the milder air of the Inner Hebrides. Hence the escarpments sweep as vast walls of almost bare rock from the level of the sea up to the serrated crests of the islands, some 2000 feet in height. Each individual bed of basalt can thus be followed continuously

Fig. 5.—*Lenticular lavas, eastern side of Svinö, Faroe Isles.*

along the fjords, and its variation or disappearance can be readily observed. Coasting along these vast natural sections, we readily perceive that the successive sheets of basalt have proceeded from no one common centre of eruption. They die out now towards one

quarter, now towards another, yet everywhere retaining the universal regularity and gentle inclinations of the whole volcanic series.

These bare rocky fronts, while permitting us to observe the want of continuity in many of the basalts, likewise afford an opportunity of following any particular sheet over the whole of its outcrop. I was particularly struck by the persistence of a dark band of basalt in the lower part of the western declivity of Kuno. This sheet can be kept in sight along the whole length of the island, at least from a point opposite to Myglesdahl in Kalso, with the exception of a short concealed space of detritus at the mouth of the recess behind the village of Kuno. It may possibly be even prolonged into the island of Bord, for a similar band is seen occupying the same position there. Its length on Kuno must be at least 6 nautical miles.

The more the basalt-plateaux of Britain and the Faroe Islands are studied, the more certain does the conclusion become that these widespread sheets of lava never flowed from a few large central volcanoes of the type of Etna or Vesuvius, but were emitted from innumerable minor vents or from open fissures. In a later part of this paper a number of the vents, which may still be seen under the overlying sheets of basalt, will be described, and I shall point out their resemblance to modern volcanic vents on the great lava-fields of Iceland.

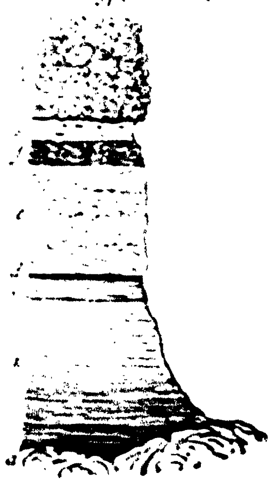
In looking at one of the sea-cliffs of the Inner Hebrides or of the Faroes, and in following with the eye its successive sheets of lava in orderly sequence of level bands from the breaking waves at the base to the beetling crest above, we are apt to take note only of the proofs of regularity and repetition in the outflows of molten rock and to miss the evidence that these outflows did not always rapidly follow each other, but were separated by intervals of varying, sometimes even of long, duration. The layer of red bole or decomposed lava, so often observable between the flows, has long been regarded as evidence of the lapse of an interval sufficiently extended to permit of considerable subaerial decay of the surface of a lava-sheet before the outflow of the next lava. But an attentive study of the plateaux discloses other and even more remarkable indications that the pauses between the consecutive basalt-beds were frequently so prolonged as to allow of extensive topographical changes being made in a district.

The occurrence, for example, of interstratifications of different kinds of sedimentary material among the lavas sufficiently demonstrates the reality of these intervals of quiescence. Where this material consists merely of volcanic tuff, it may only point to a continuance of volcanic activity in the form of fragmentary discharges during pauses in the outpourings of molten rock. In general, however, there is not only tuff but non-volcanic sediment arranged in definite layers, that show the action of running water. The various clays (bauxite, lithomarge, etc.) and ironstones which lie between the basalts of Antrim, besides their geological interest, have now considerable economic importance. The clays, in particular, are much in request as sources for the manufacture of aluminium. Neither among the Western Isles of Scotland nor in

the Faroes has any one definite platform yet been traced out on which such clays are extensively developed. But various minor and perhaps more local deposits in these regions might be examined as possibly available for industrial purposes. One of the most promising localities lies on the western side of Skye, at the mouth of Loch Bracadale, where, on the face of the great cliff of Rudha nan Clach, some conspicuous bands of lilac and red are interspersed among the basalts. These bands were noticed by Macculloch, who described them as varieties of 'iron-clay.'[1] I have not had an opportunity of examining them, except from the sea at a little distance. But they suggest a similarity to some of the variegated clays between the upper and lower basalt series of Antrim. The coal-bearing platform of the Faroes might also be followed along its outcrop, with the object of ascertaining whether any local deposits of similar clays exist there.

As an illustration of the diversity of deposits sometimes observable between the basalts, I give here a section exposed on the eastern side of Sudero in the Faroe Islands—a locality often visited and described in connexion with its coal-seams (fig. 6). At the base lies a sheet of basalt (*a*) with an irregularly lumpy upper surface. It may be remarked that the group of basalts below this stratified intercalation is marked by the occurrence of numerous columnar sheets, some of them possibly sills, and also more massive, solid, and durable basalts than the sheets above. The lowest of the intercalated sediments are light-coloured clays, passing down into dark nodular mudstone and dark shale, the whole having a thickness of at least 20 feet (*b*). These strata are succeeded by (*c*) pale clays with black plant-remains, about 3 feet thick. Immediately above this band comes the coal or coaly layer (*d*), here about 6 inches thick, which improves in thickness and quality farther inland, where it has been occasionally worked for economic purposes. A deposit of green and brown volcanic mudstone (*e*), 12 feet in thickness, overlies the coal and passes under a well-bedded granular green tuff and mudstone 3 feet thick (*f*). The uppermost band is another volcanic mudstone (*g*) 4 feet in thickness, dark green in colour, and more or less distinctly stratified, with irregular concretions, and also pieces of wood. Above this layer comes another thick overlying group of basalts (*h*) distinguished by their abundantly amygdaloidal

Fig. 6.—*Section at Frodbonyp, Sudero.*



[1] 'Description of the Western Islands of Scotland,' vol. i. (1819) p. 378.

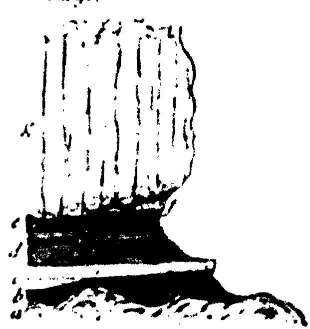
character, and by their weathering into globular forms which at a little distance give them a resemblance to agglomerates.

We have here an intercalated group of strata upwards of 40 feet thick, consisting partly of tuffs and partly of fine clays, which may either have been derived from volcanic explosions or from the atmospheric disintegration of basaltic lavas. Through some of these strata abundant carbonaceous streaks and other traces of plants are distributed, while among them lies a band almost wholly composed of compressed vegetation. Unfortunately none of the strata at this locality seem to have preserved the plant-remains with sufficient definiteness for identification. There can be no doubt, however, that they were terrestrial forms like those of Mull and Antrim.

This coal, with accompanying sedimentary deposits, has been traced through Sudero, and another outcrop, possibly of the same horizon, occurs on Myggenaes, the extreme western member of the Faroe group, at a distance of some 40 miles.[1]

Though good coal is not well developed in the Tertiary volcanic plateaux of the British Isles, I have found coaly layers to be extremely abundant there. And as the vegetable matter may confidently be assumed always to indicate terrestrial vegetation, the presence of these carbonaceous bands may be regarded as good evidence of some lapse of time between the eruption of the basalts which they separate. I have observed that they not infrequently form the highest member of a group of intercalated sediments between two sheets of basalt. This relation is strikingly exhibited in the isle of Canna in connexion with the river-gravels, to which more detailed reference will be made in a later part of this paper. But I may here cite an interesting example which occurs at the base of the lofty sea-cliff of An Ceannaich, to the south of Dunvegan Head, on the western coast of Skye (fig. 7).

Fig. 7. *Intercalated group of strata between basalts. An Ceannaich, western coast of Skye.*



At the base of the precipice ledges of a highly amygdaloidal basalt (*a*) show a singularly scoriaceous and amygdaloidal structure, with abundant and beautiful zeolites, the hollows of the upper surface of the sheet being filled in with dark brown carbonaceous shale, forming a layer from 1 to 14 inches thick, marked by coaly streaks and lenticles (*b*). A band of green and yellow sandstone (*c*) next supervenes, which, from its pale colour, attracts attention from a distance, and led me, while yachting along the coast, to land at the locality, in the hope that it might prove to be a plant-bearing limestone. This

[1] See in particular J. Geikie, Trans. Roy. Soc. Edin. vol. xxx. (1880) p. 220.

sandy stratum is only some 3 or 4 inches thick at the northern end of the section, but increases rapidly southward to a thickness of as many feet or more, when, owing to the cessation of the underlying shale, it comes to lie directly on the amygdaloid and to enclose slaggy portions of that rock. Immediately above the sandstone 2 or 3 feet of fissile shale, black with plant-remains (*d*), include brown layers that yield to the knife like some oil-shales. The next stratum is a seam of coal (*e*) about 1 foot thick, of remarkable purity. It is glossy, hard, and cubical, including layers that break like jet. It has been succeeded by a deposit of green sand (*f*), but while this material was in course of deposition another outpouring of lava took place, whereby the terrestrial pool or hollow in the lava-field in which the group of sedimentary materials accumulated was filled up and buried. This lava is about 20 feet thick, and consists of a coarsely-crystalline, jointed dolerite with highly amygdaloidal upper and under surfaces. Its slaggy bottom has caught up or pushed aside the layer of green sand, so as to lie directly on the coal, and has there been converted into that earthy modification so familiar under the name of 'white trap' among our coal-fields. It is interesting to find that this kind of alteration, where molten rock comes in contact with carbonaceous materials, is not confined to subterranean sills, but may show itself in lavas that have flowed over a terrestrial surface.

From the frequent intercalation of such local deposits of sedimentary material between the basalts we may reasonably infer that during older Tertiary time the rainfall in North-western Europe was copious enough to supply many little lakes and streams of water. As the surface of the lava-fields decayed into soil, vegetation spread over it, so that perhaps for long intervals some tracts remained green and forest-clad. But volcanic action still continued to show itself, now from one vent, now from another, these wooded tracts were buried under overflows of lava, and, the watercourses being filled up, their streams were driven into new channels, and other pools and lakes were formed. Some of the evidence for this part of the volcanic history will be given in the IIIrd section of the present paper.

II. The Vents.

Though the abundant vents, which, to judge from the lenticular nature of the lavas, were dotted over the surface of the Tertiary volcanic plains, have for the most part been buried under sheets of molten material, the progress of denudation has laid bare some of them. It is chiefly along the coast-line that this process of excavation has successfully taken place. The interior of the islands is often loaded with peat, covered with herbage, or strewn with glacial detritus; and even where indications of the vents are there to be detected, it is not always possible to ascertain the true limits and connexions of these old volcanic chimneys. But where the structure of the plateaux has been laid bare along ranges of rocky precipice, the vents have sometimes been so admirably dissected by the sea that

every feature of their arrangement can be satisfactorily determined. In the memoir already cited I have described a number of examples from the interior. I now proceed to give an account of other instances from the coast-sections.

I will begin with a group of vents in the Faroe Islands which display with singular clearness some of the most characteristic features of this part of the volcanic record. And here let me remark that, although these islands have been so frequently visited and so often described that their general structure is sufficiently well known, they present in their details so vast a mass of new material for the illustration of volcanic action that they deserve a far more minute and patient survey than they have yet received. They cannot be adequately mapped and understood by the traveller who merely sails round them. They must be laboriously explored, island by island and cliff by cliff. While I cannot pretend to more than a mere general acquaintance with their structure, I have learnt by experience that one may sail near their precipices and yet miss some essential features of their volcanic structure. Last year I passed close to the noble range of precipices on the western side of Stromö, at the mouth of the Vaagöfjord, and sketched the sill which forms so striking a part of the geology of that district (figs. 24 & 25, pp. 380, 381). But I failed to observe an even more remarkable and interesting feature at the base of the same sea-cliffs. This last summer, probably under better conditions of light, I was fortunate enough to detect with my field-glass, from the deck of the yacht, what looked like a mass of agglomerate. Steaming inshore I was delighted to find, as the vessel drew nearer to the cliff, that the agglomerate assumed definite boundaries and occurred in several distinct patches, until at last it presented the unmistakable outlines of a group of vents underlying and overspread by the bedded basalts of the plateau. I at once got into the longboat, and, favoured by an unusually calm sea, was enabled to steer into every nook and round every buttress and islet of this part of the coast-line.

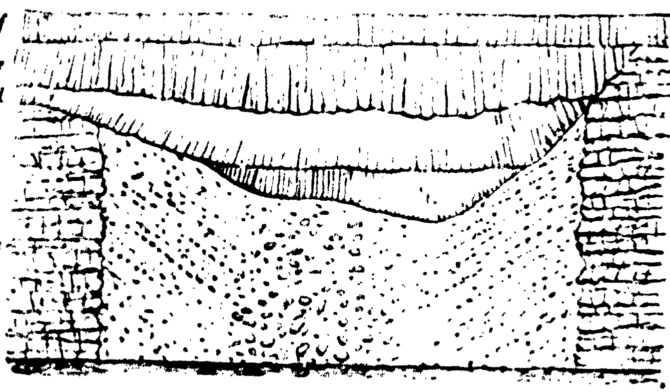
The basalt-plateau here presents to the western ocean a nearly vertical escarpment which must reach a height of at least 1000 feet (see fig. 24, p. 380), and displays a magnificent section of the bedded lavas. The lower part of this section shows chiefly the banded structure already described, the layers of different consistency being etched out by the weather in such a way as to give them the look of stratified rocks. In the upper part of the precipice columnar and jointed or prismatic sheets are more common, but the most prominent band is the great sill just alluded to, and to which further reference will be made in the sequel.

In the course of the gradual retreat of the cliff, as the waves tunnel its base and slice after slice is detached from its vertical front, a group of at least five small vents has been uncovered lying along a nearly north-and-south line. Of two of these a segment remains still on the cliff-wall and passes under the basalts; the others have been dissected and half cut away from the cliff, while groups of stacks and rocky islets of agglomerate may mark the

positions of others almost effaced. The horizontal distance within which the vents are crowded is probably less than half a mile, but the lofty proportions of the precipice tend to lead the eye to underestimate both heights and distances.

The agglomerate is a thoroughly volcanic rock, consisting of blocks of all sizes of various basalts, among which large slags are specially conspicuous, the whole being wrapped in a granular matrix of comminuted volcanic detritus. The arrangement of this material is best seen in the fourth vent (Pl. XV. and fig. 8). In this characteristic

Fig. 8.—*Section of the same neck as that shown in Pl. XV.*



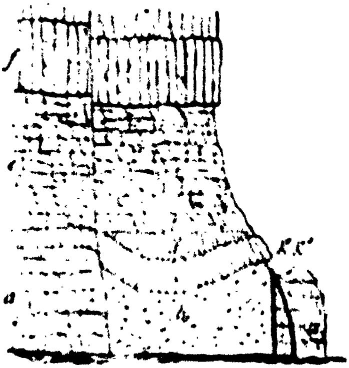
volcanic neck (*b* in fig. 8) the boundary walls, as laid bare on the face of the precipice, are vertical, and are formed of the truncated ends of the banded lavas (*a a*) which have been blown out at the time of the formation of the orifice. The visible diameter of the vent was roughly estimated by me to be about 100 yards. No appreciable alteration was observed in the ends of the lavas next the vent. The agglomerate is coarsest in the centre, where huge blocks of slaggy lava lie imbedded in the amorphous mass of compacted débris. On either side of this structureless central portion the agglomerate is distinctly stratified from the walls towards the middle, at angles of 30° to 35°. Even from a distance it can be observed that the upper limit of the agglomerate is saucer-shaped, the sloping sides of the depression dipping towards the centre of the neck at about the same angle as the rudely stratified agglomerate underneath. From the bottom of this basin to the sea-level may be a vertical distance of some 30 yards. The basin itself has been filled up by three successive flows of basalt, of which the first has merely overflowed the bottom, the second (*d*), entering from the northern rim of the basin, extends across to the southern slope, while the third (*e*), also flowing from the north, has filled up the remainder of the hollow and extended completely across it. The next succeeding lava (*f*) stretched over the site in such a way

Volcanic neck piercing and overlain by the plateau-basalts, Stromö, entrance of Vaagofjord, Faroe Islands.
(From a photograph by Col. John Evans.)

as to bury it entirely, and to provide a level floor for the piling up of the succeeding sheets of basalt.

The second vent, which is represented in fig. 9, exhibits the same features, but with some additional points of interest. It measures roughly about 20 yards in diameter at the sea-level, rises through the same group of banded basalts (*a a*), and is filled with a similar agglomerate (*b*). Its more northerly wall is now coincident with a line of fault (*h*) which ascends the cliff, and probably marks some subsidence after the eruptions had ceased. The southern wall shows that a dyke of basalt (*g*) has risen between the agglomerate and the banded basalts, and that a second dyke (*g'*) traverses the latter at a distance of a few feet. In this instance, also, the upper surface of the agglomerate forms a cup-shaped depression which has been filled in by two successive streams of lava (*c*, *d*). Among the succeeding lavas (*e*) a prominent sill (*f*) has been intruded, to which more special reference will be made in the sequel.

Fig. 9.—*Volcanic neck close to that shown in Pl. XV. & fig. 8.*



These necks are obviously volcanic vents belonging to the time of the basaltic eruptions. They have been drilled through the basalts of the lower part of the cliff, but have been buried under those of the central and higher parts. The arrangement of their component materials in rude beds dipping towards the centre of the vent shows that the ejected dust and stones must have fallen back into the orifice so as to be rudely stratified towards the centre of the chimney, which was finally closed by its own last discharges of coarse detritus. The saucer-shaped upper limit of the agglomerate seems to indicate that after the eruptions ceased each vent remained as a hollow or *maar* on the surface of the lava-fields. And the manner in which they are filled with successive sheets of basalt shows that in course of time other eruptions from neighbouring orifices gave forth streams of lava which, in flowing over the volcanic fields, eventually buried and obliterated each of the vents.

In the destruction of the precipice some of the vents have been so much cut away that only a small part of the wall is left, with a portion of the agglomerate adhering to it. The third neck, for instance, affords the section represented in fig. 10, p. 346, where the horizontal sheets of basalt (*a*) have still a kind of thick pellicle of the volcanic detritus (*b*), adhering to what must have been part of the side of the orifice of eruption. The waves have cut out a cave at the base, so that one can, by boat, get behind the agglomerate and see the margin of the volcanic funnel in the roof overhead.

In the fragment of geological history so picturesquely laid bare on the Stromo cliffs we are presented with a significant illustration of what seems to have been a common type of volcanic vent in the Tertiary basalt-plateaux. By the fortunate accident that denudation has not proceeded too far, we are able to observe the original tops of at least two of the vents, and to see how such volcanic orifices, which were doubtless abundant all over these plateaux, came to be entombed under the ever-increasing pile of accumulating basalt.

Fig. 10.—*Section of wall of another neck of agglomerate in the same group with those represented in Pl. XV. & figs. 8, 9.*

There is still one feature of interest in these cliff-sections which deserves notice here. Every geologist who has studied the composition of the basalt-plateaux has remarked the comparatively insignificant part played by tuffs in these volcanic accumulations. Hundreds of feet of successive basalt-sheets may often be examined without the discovery of any intercalation of fragmental materials, and even where such intercalations do occur they are for the most part quite thin and extremely local. I found it impossible to scale the precipice for the purpose of ascertaining whether around the Stromo vents, and connected with them, there might not be some beds of tuff interstratified between the basalts. If such beds exist, they can be of only trifling thickness and extent. Here, then, are examples of once active vents, the funnels of which are still choked up with coarse fragmentary ejections, yet from which little or no discharge of ashes and stones took place over the surrounding ground. They seem to have been left as *maare* or crater-like hollows on the surface of the lava-fields.

The next example of a neck which I will describe occurs on the cliffs that form the southern side of the sheltered inlet known as Portree Bay in the Isle of Skye. These cliffs, the seaward escarpment of the basalt-plateau, rise above a platform of Jurassic sandstones and shales. At Camas Garbh, where they have been trenched by a small rivulet, aided by the presence of two dykes, the gully thus formed exposes a section of a neck of agglomerate that underlies the basalts of the upper half of the cliff. This neck is connected with a thick deposit of volcanic conglomerate and tuff which, lying between the basalts, extends from the neck to a considerable distance. The general relations of the rocks in this cliff are represented in fig. 11.

The agglomerate (*b* in fig. 11) is quite tumultuous, and here and there strikingly coarse. Some of its included blocks measure 5 feet in length. These fragments represent most of the varieties of the lavas of the district. Large slaggy masses are abundant, and sometimes exhibit the annelid-like elongation of the vesicles

to which I have referred as occasionally displayed by the plateau-basalts. More than 60 feet of agglomerate is visible in vertical height from where its base is concealed by débris and vegetation to where its upper surface passes under a banded rock to be afterwards described. That this unstratified mass of volcanic ejectamenta marks the site of the vent can hardly be doubted, although denudation has not revealed the actual walls of the chimney. The steep grassy slopes do not permit of the relations of the rocks being everywhere seen, but the agglomerate appears to pass laterally into finer, rudely stratified material of a similar kind, which extends east and west of the vent as a thick deposit between the bedded

Fig. 11.—*Section of volcanic vent and connected lavas and tuffs. Scorr, Camas Garbh, Portree Bay, Skye.*

a. Rudely-bedded dull green tuff; *b.* Coarse agglomerate; *c.* Prismatic basalt; *d.* Massive jointed basalt; *e.* Red banded decomposing rock probably of detrital origin; *f.* Plateau basalts prismatic and rudely columnar; *g.* Dyke of dolerite somewhat vesicular, 5 to 6 feet broad; *h.* Basalt dyke 2 to 3 feet broad; *i.* Dyke or sill of basalt similar to *h* and possibly connected with it.

basalts. Possibly denudation has only advanced far enough to lay bare the crater and its surrounding sheets of fragmentary material, while the chimney lies still buried underneath.

East of the agglomerate the fragmentary material becomes less coarse, and shows increasing indications of a bedded arrangement. Close to the agglomerate the dip of the coarse tuff is towards that rock at about 10°. A few yards farther east a sheet of very slaggy basalt is seen to lie against the tuff, which it does not pierce. The vesicles in this adhering cake of lava have been pulled out in the direction of the slope till they have become narrow tubes 4 or 5 inches long and parallel to each other. Some parts of this rock have a curved ropy surface, like that of well-known Vesuvian lavas, suggestive of the molten rock having flowed in successive thin viscous sheets down the slope, which has a declivity of about 30°. This part of the section may possibly preserve a fragment of the actual inner slope of the crater, formed of rudely bedded tuffs.

Continuing still eastward, we find the feebly stratified tuff (*a*) to be perhaps 200 feet thick. It forms a grassy declivity that descends from the basalt-escarpment above to the grass-covered platform which overlies a lower group of basalts. The visible portion of this tuff presents a thoroughly volcanic character, being made up of the usual dull dirty-green granular paste, through which are dispersed angular and rough lumps of slag and pieces of more solid basalt varying up to 1 or 2 feet in length. These stones are generally disposed parallel to the indistinct bedding, but are sometimes placed on end as if they had assumed that position on falling from an explosive shower. Among the smaller stones, pieces of a finely vesicular basic pumice are frequent and are among the most strikingly volcanic products of the deposit. From a characteristic sample of these stones, a thin slice was prepared and placed in Mr. Harker's hands. The following are his observations on it:—

'A very compact dark-grey rock, amygdaloidal on a minute scale. The lighter grey crust is probably due merely to weathering, and the specimen seems to be a distinct fragment, not a true bomb.

'The slice [6662] shows it to be essentially a brown glass with only occasional microscopic crystals of a basic plagioclase. It has been highly vesicular, and the vesicles are now filled by various secondary products, including a chloritic mineral, nearly colourless and singly refracting in thin section, and a zeolite.'

Tracing now the tuff from the western side of the vent, we can follow it to a greater distance. No abrupt line can be detected here, any more than on the other side between the agglomerate and the tuff. The latter rock extends under the overlying plateau of basalt, at least as far west as Portree Loch, a distance of fully a mile, but rapidly diminishes in thickness in that direction. Traces of what is probably the same tuff can be detected between the basalts at Ach na Hannait, more than 3 miles to the south. It is thus probable that from the Portree vent fragmentary discharges took place over an area of several square miles.

Above the agglomerate of this vent two lavas may be seen to start towards opposite directions. One of these (*c* in fig. 11) begins immediately to the east of the two dykes. It is a dull prismatic basalt with a slaggy bottom, its vesicles being pulled out in the direction of the general bedding of the section. It descends by a twist or step, and then lies on the gently inclined surface of the tuff which dips towards the agglomerate. Farther east it increases in thickness and forms the lowest of the basalt-sheets of the cliff. The lava that commences on the western side of the vent (*d* in fig. 11) is a massive jointed basalt, which, though not seen at the vent, appears immediately to the west of it and rapidly swells out so as to become one of the thickest sheets of the locality. It lies upon the rudely bedded tuff, and is covered by the other basalts of the cliff.

That these two basalts came out of this vent cannot be affirmed. If they did so at different times, their emission must have been followed by the eruption which cleared the funnel and left the

central mass of agglomerate there. But that some kind of saucer-shaped depression was still left above the site of the vent is indicated by the curious elliptical mass of rock (*e*) that lies immediately above the agglomerate from which it is sharply marked off. This is one of the most puzzling rocks in the district, probably in large measure owing to its advanced state of decay. It is dull red in colour and decomposes into roughly parallel layers, so that at a short distance it looks like a bedded tuff, or like some of the crumbling varieties of banded lavas. I could not obtain specimens fresh enough to put its nature and origin beyond dispute. Whatever may have been its history, this ferruginous rock rests in a saucer-shaped depression lying directly above the agglomerate of the vent. The form of this depression, like that of the Faroe necks, corresponds fairly well with what we may suppose to have been the final position and shape of the crater of the little volcano. The rock that occupies the hollow dies out towards the east on the face of the cliff, and the prismatic basalt (*e*) is then immediately covered by the rest of the basalt-sheets of the plateau (*f*). On the western side its precise termination is concealed by grass. But it must rapidly dwindle in that direction also, for not many yards away it is found to have disappeared, and the basalts (*d* and *f*) come together.

Though the decayed state of this rock does not warrant any very confident opinion regarding its history, I am inclined to look upon it as a deposit of much disintegrated volcanic detritus washed into the hollow of the old crater when it had become filled with water, and had passed into the condition of a *maar*. The peculiarly oxidized condition of its materials points probably to long atmospheric exposure, and an examination of the surrounding parts of the district furnishes more or less distinct evidence that a considerable lapse of time did actually intervene between the cessation of the eruptions of the Portree volcano and the next great basalt-floods of this part of Skye.

That volcanic eruptions from other vents continued after this Portree example had become extinct is proved by the great sheets of basalt (*f*) that overspread it and still bury a large tract of the fragmentary material which it discharged. At a later time a fissure that was opened across the vent allowed the uprise of a basalt dyke (*g*), and subsequently another injection of similar material took place along the same line of weakness (*h* and *i*).

Before leaving this interesting locality we may briefly take note of the distribution of the ashes and stones ejected by the volcano, and the evidence for the relative length of the interval between the outflow of the lavas below and that of those above the tuff and volcanic conglomerate. Admirable sections of these deposits may be traced along the base of the cliffs for a mile to the west of the vent. They thin away so rapidly in that direction that at a distance of ½ mile they do not much exceed 50 feet in thickness. At Camas Bàn they consist mainly of a fine, dull-green, granular, rudely stratified basalt-tuff, through which occasional angular

pieces of different lavas and rough slags are irregularly dispersed. These stones occur here and there in rows, suggestive of more vigorous discharges, the layers between the platforms of coarser detritus being occupied by fine tuff. Some of the ejected blocks are imbedded on end—an indication of the force with which they were projected and fell nearly a mile from the crater.

The upper parts of the tuff pass upward into fine yellow, brown, and black clays a few feet in thickness, the darker layers being full of carbonaceous streaks. On this horizon the coal of Portree was formerly mined. The workings, however, have long been abandoned, and, owing to the fall of large blocks from the basalt-cliff overhead, the entrance to the mine is almost completely blocked up. One wooden prop may still be seen keeping up the roof of the arch, which is here a slaggy basalt.

East and south-east of the Portree vent, extensive landslips of the volcanic series and of the underlying Jurassic formations make it hardly possible to trace the continuation of the tuff-zone in that direction. To the south, however, at a distance of rather more than 3 miles, what is probably the same stratigraphical horizon may be conveniently examined from Ach na Hannait for some way to the north of Tianavaig Bay. At the former locality the calcareous sandstones of the Inferior Oolite are unconformably covered by the section represented in fig. 12. At the bottom of the volcanic series lies a sheet of nodular dolerite with a slaggy upper surface (*a*). Wrapping round the projections and filling up the depressions of this lava comes a thin group of sedimentary strata from 1 or 2 to 18 inches or more in thickness (*b*). These deposits consist of hardened shale charged with macerated remains of linear leaves and other plant-remains, including and passing into streaks of coal, which may be looked upon as probably occupying the same horizon with the coal of Portree. But here, instead of reposing on a mass of stratified tuff, the carbonaceous layers lie on one of the bedded lavas. The tuff has died out in the intervening 3 miles, yet that some of the discharges of volcanic detritus reached even to this distance, and that they took place during the accumulation of these layers of mud and vegetation is shown by the occurrence in the shales of pieces of finely amygdaloidal basalt from less than 1 to 6 inches in length, likewise of lapilli of a fine, minutely cellular, basic pumice, like some varieties of palagonite. The overlying dolerite (*c*) becomes finely prismatic at its

Fig. 12.—*Section of the volcanic series at Ach na Hannait, south of Portree, Skye.*

PART OF A VOLCANIC NECK AT THE EASTERN END OF THE ISLAND OF CANNA.
(See also fig. 15.) (From a photograph by Miss THOM, of Canna.)

junction with the sedimentary layers, and has probably indurated them.

This intercalation of a shaly and coaly band among the lavas can be followed northward along the coast. In some places it has been invaded by dykes, sills, and threads of basalt on the most remarkably minute scale, of which I shall give some account in a later part of this paper (see fig. 21, p. 375). North of Tianavaig Bay—that is, about ½ mile nearer to the Portree vent—a perceptible increase in the amount of volcanic material is observable among the shales and leaf-beds. Not only are lapilli of basic pumice abundant, but the volcanic detritus has accumulated here and there in sufficient amount to form a band of dull greenish-brown tuff.

I have already alluded to the characteristic fact that the interstratifications of sedimentary material among the basalt-plateaux frequently terminate upward in leaf-beds, thin coals, or layers of shale, full of indistinctly preserved remains of plants, and some further striking illustrations of this feature will be described from the river-shingles and other evidences of water-action during the volcanic period in the islands of Canna and Sanday. There cannot be any doubt that the vegetation thus preserved was terrestrial. It probably grew not far from the sites where its remains have been preserved. Leaves and seeds would naturally be blown or washed into pools on the lava-fields, and would gather there among the mud and sand carried by rain from the surrounding ground. Such a topography and such a sequence of events point to intervals of longer or shorter duration between the successive outpourings of basalt. It was probably during one of these intervals of quietude that the crater of the Portree volcano became a *maar*, and was finally silted up.

There is one last example of a volcanic vent, of which a description may here be given. It occurs at the eastern end of the island of Canna. A portion of it projects from the grassy slopes, and rises vertically above the beach as a picturesque crag in front of the precipice of Compass Hill (Pl. XVI.). But the same rock may be traced southward to the Coroghon Mor, and north-westward in the lower part of the cliffs to a little beyond the sea-stack of An Stoll. It has thus a diameter of at least 3000 feet. Westward it passes under the conglomerate to be afterwards described, and its eastern extension has been concealed by the sea.

The materials that fill this vent consist of a typical agglomerate composed entirely, or almost entirely, of volcanic detritus. The imbedded blocks vary up to 8 feet in diameter or even more. They are chiefly fragments of various basalts and andesites, generally vesicular or amygdaloidal. Some of these, which have evidently been broken off already consolidated lavas, are angular or subangular in shape, and their steam-holes are cut across by the outer surfaces of the stones. Where filled with calcite, zeolite, etc., the amygdules so exactly resemble those of the bedded basalts of the

plateaux that, as already remarked, we must believe them to have been already filled by infiltration before the disruption of the rocks by volcanic explosions. Other blocks are true bombs, with a fine-grained crust outside and a more cellular texture inside, the vesicles of the outer crust being sometimes dragged round the surface of the stone. The variety of materials included among the ejected blocks and the abundance of pieces of the red bole which so generally separates the plateau-basalts indicate that a considerable thickness of bedded lavas has probably been broken through by the vent. Besides the volcanic materials, occasional angular pieces of red (Torridon) sandstone may be observed in the agglomerate. The paste is a comminuted mass of the same material as the blocks, tolerably compact, and entirely without any trace of stratification.

The actual margin of this vent has nowhere been detected by me. We never reach here the base of the volcanic series, for it is sunk under the sea-level. On the other hand, the upper limits of the agglomerate have been partially effaced or obscured by the thick conglomerates which overlie it. There can be no doubt, from the breadth of ground across which the agglomerate can be followed along the shore, that the vent must have been one of somewhat exceptional size, perhaps not less than $\frac{3}{4}$ mile in diameter, unless, indeed, there were more than one in close proximity. That it continued in vigorous eruption may be judged from the amount of material ejected from it, the large size of its blocks, and the distance to which they were sometimes thrown.

The pieces of Torridon Sandstone were no doubt derived from the extension of that formation underneath Canna. On the opposite island of Rum these pre-Cambrian red sandstones are copiously developed. They form there a platform through which the Tertiary volcanic series has been erupted. Several remaining outliers of the bedded basalts on the western side of that island show that the basalt-plateau of Small Isles once covered that area, and that it rested immediately on the inclined edges of the Torridon Sandstone. Probably the same structure stretches westward under Canna and Sanday. No traces of any Jurassic strata have been detected beneath the volcanic rocks of Rum, though they are so well developed a few miles to the east in the island of Eigg. Either they were not deposited over the pre-Cambrian rocks of Rum, or they had been removed from that ancient ridge before the beginning of the Tertiary volcanic period. Certainly I have not detected a single recognizable fragment of any Jurassic sedimentary rock in the agglomerate of Canna.

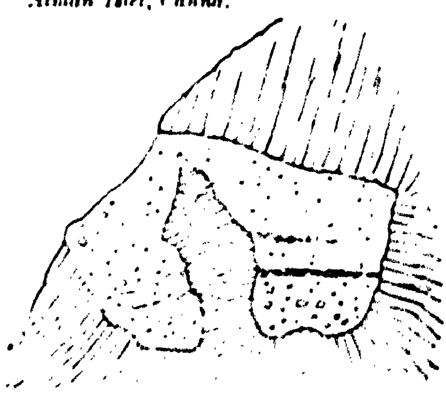
This Canna vent exhibits, better than is usually shown, the occurrence of dykes and irregular injections of lava through the agglomerate. A large mass of a finely columnar basalt ascends from the beach at Garbh Asgarnish. A similar rock forms several detached crags a little farther south, particularly in the headland of Coroghon Mòr and the island of Alman. Here the basalt is

beautifully columnar, its slender prisms curving from a central line until their ends abut against the agglomerate. The truly intrusive character of this basalt is well shown on the southern front of Coroghon Mòr, and on the northern face of Alman, as represented in the accompanying diagrams (figs. 13 & 14).

Fig. 13.—*Columnar basalt invading agglomerate of volcanic vent. Coroghon Mòr, Isle of Canna. (Height more than 20 feet.)*

Although there is no conclusive evidence that these intrusions belong to the time of the activity of the vent, yet they differ so much from the ordinary dykes (one of which also cuts the agglomerate and ascends through the conglomerates and basalts above), are confined so markedly to the vent and its immediate proximity, and resemble so closely the basalt injections of other vents, such as those of the Carboniferous and Permian necks of Scotland, that they may with every probability be regarded as part of the mechanism of the Canna volcano.

Fig. 14.—*Columnar basalt invading volcanic conglomerate. Northern side of Alman Islet, Canna.*



Though the form and size of the vent of this volcano cannot be precisely defined, the upper part of its agglomerate is dovetailed in the most interesting way with a series of coarse conglomerates, which indicate strong aqueous action in this part of the volcanic area during the time of the eruption of the plateau-basalts. As the history of the eruptions of the Canna vent is so closely linked with that of some powerful river which flowed across the lava-fields in this part of Western Scotland, I reserve further account of it for the next section of this paper.

III. The Rivers of the Volcanic Period.

Many years ago I communicated to this Society an account of an ancient river-channel which, during the volcanic period, had been eroded on the surface of the basalt-plateau, and of which a small portion had been preserved under a stream of pitchstone-lava that had flowed into and buried it.[1] This watercourse, now marked by the picturesque ridge of the Scuir of Eigg, was shown to have been excavated by a stream which came from the north-east or east, and to be younger, not only than the plateau-basalts of the district, but younger even than the dykes which cut these basalts. Yet that it belonged to the volcanic period was proved by the manner in which it had been sealed up and preserved under the black glassy lava of the Scuir.

Within the last two years I have met with other and more abundant evidence of river-action in the same region of the Inner Hebrides. This evidence, however, belongs to an earlier part of the volcanic period. It reveals that a powerful river, flowing westward from the Highland mountains, swept over the volcanic plain, while the sheets of basalt were still being poured forth, and while volcanic eruptions were taking place from cones of slag.

This interesting record is preserved in the islands of Canna and Sanday. The gravels and silts of the river are there found intercalated between the basalts, mingled with volcanic detritus, probably ejected from the active vent already described. On visiting these islands for the first time last year, I found so much that was new to me in regard to the history of Tertiary volcanic action, and which demanded a careful survey, that I returned to the locality this summer and remained in Canna until I had mapped that island and its dependencies upon the Ordnance Survey sheets on the scale of 6 inches to a mile.

Macculloch, in his account of Canna and Sanday, took notice of the intercalation of beds of conglomerate among the basalts. He regarded these detrital rocks as having been arranged under water and as marking pauses in the deposition of the sheets of 'trap.' He likewise gave two diagrams in illustration of the relations of the conglomerates, but he expressed no definite opinion as to the origin of these rocks, though in one passage he seems to have inclined towards the belief that they were formed in the sea.[2] Since his time, so far as I am aware, no fresh light has been thrown upon the subject.

The conglomerates are best developed at the eastern end of Canna, where the cliffs present the structure illustrated in fig. 15. At the base, and passing under the level of the sea, lies the agglomerate (*a*) of the vent already described. This rock has a somewhat uneven upper surface, which rises in places about 150 feet above high-tide mark. Here and there it shades off upward into

[1] Quart. Journ. Geol. Soc. vol. xxvii (1871) p. 303.
[2] 'Description of the Western Islands,' vol. i (1819) pp. 449, 457, pl. xix. figs. 2 & 3.

the conglomerate that overlies it: waterworn pebbles appear among its contents, and rude traces of bedding begin to show themselves, until, within the course of a few feet, we pass upward into an undoubted conglomerate. Elsewhere, however, and particularly along the precipices west of Compass Hill, the two deposits are

Fig. 15.—Section of the cliffs below Compass Hill, Isle of Canna.

more distinctly marked off from each other. The agglomerate has there a hummocky, irregular upper surface, as if it had been thrown down in heaps. The hollows between these protuberances have been filled up with conglomerate and sandstone, forming the base of the thick overlying deposits.

It is thus clear that the loose materials of the vent were directly exposed at the surface when the conglomerate was accumulated, and, indeed, that these materials served to supply some of the detritus of which the conglomerate consists. The absence of any trace of a cone and crater at the vent may perhaps be explicable on the supposition that their incoherent material was washed down by the currents that swept along and deposited the conglomerate.

The mass of sedimentary material (*b*) which overlies the agglomerate of the vent forms a conspicuous feature along the lower half of the precipices at the eastern end of Canna. It rises to a height of 250 to 300 feet above sea-level, and must reach a maximum thickness of probably not less than 100 to 150 feet. It gradually descends in a westerly direction both along the northern cliffs and in the lower ground round Canna Harbour, insomuch that in about a mile, owing to the gentle westerly dip of the whole volcanic series, combined with the effect of a number of small faults, it passes under the level of the sea.

Great variation in the character of the detritus composing this thick group of strata may be observed as it is followed westward. On the cliffs below Compass Hill, as represented in fig. 15, p. 355, a coarse conglomerate with waterworn stones, hardly to be distinguished from the volcanic agglomerate of the vent, shows more or less distinct bedding, or at least a succession of coarser and finer bands. Towards its base it encloses numerous pieces of Torridon Sandstone, sometimes subangular, but often so well and smoothly rounded as to show that they must have been long subjected to the action of moving water. It is further observable that, while in the agglomerate the volcanic stones have rough surfaces, those in the conglomerate begin to show increasing evidence of attrition, until, as the deposit is traced upward, they become almost as well rounded and waterworn as the non-volcanic stones which have come from another district.

Yet amidst and overlying these proofs of transport from some little distance lie abundant huge slags and blocks of amygdaloidal lava, sometimes closely aggregated, sometimes scattered through a volcanic tuff or ashy sandstone. The composition and structure of these stones, and the manner of their dispersion through the deposit, leave little doubt that they were ejected from the vent. We are thus confronted with the interesting fact that, while the materials of the volcanic cone were being washed down by running water, eruptions were still taking place. But by degrees these indications of contemporaneous volcanic activity disappear. The detrital materials become coarser and more distinctly water-rolled, until they pass into greenish sandstones and fine conglomerates. Yet the matrix even of these higher sediments is largely composed of fine volcanic detritus, and probably points to occasional discharges of dust and ashes.

Various sills or intrusive sheets have been injected into this sedimentary group along the precipices at the eastern end of Canna, and form there lenticular bands. One of these (*c*) is shown in fig. 15.

Immediately above the massive greenish pebbly sandstone (*d*) which caps the stratified series, lies a group of basalts (*e*), composed of several distinct beds, having a united thickness of from 80 to 100 feet. The lowest of these has a regular columnar structure, while those overlying it exhibit the confused starch-like grouping of curved and rather indistinctly-formed prisms, which is so characteristic a structure in the plateaux.

The next band in upward succession is one of conglomerate (*f*), which runs as a continuous and conspicuous feature along the upper part of the cliff. This rock presents in many respects a strong contrast to the conglomerates underneath. It is dull green to yellow in colour, and is well stratified, being marked by the interstratification of finer layers, and passing down into a band of pebbly sandstone, which rests immediately on the basalt (*e*). Its component stones are thoroughly waterworn, ranging up to 6 inches or even more in length. But its most distinctive character lies in the nature of its pebbles. Instead of consisting mainly of volcanic materials, these stones have almost all been transported for some distance. They include abundant fragments of Torridon Sandstone, gneiss, schists, grits, and other rocks like those in Rum and Western Inverness-shire. No such rocks exist *in situ* in Canna. The nearest tract of Torridon Sandstone is in Rum, about 4 miles to the eastward. But the pieces of schist and epidotic grit, like the rocks of the Western Highlands, must have travelled at least 30 miles.

It is important to observe that all these transported stones indicate a derivation from some source lying to the eastward of Canna. The evidence in this respect agrees with that furnished by the ancient river-gravel under the pitchstone of the Scuir of Eigg. It is clear that the waters which found their way across the lava-fields of this part of the Inner Hebrides took their rise among the mountains of Inverness-shire.

The conglomerate now described is from 40 to 50 feet thick. It can be followed along the face of the cliffs for more than a mile on the northern side of Canna. Less persistent on the southern side, its outcrop strikes from the edge of the precipice inland, keeping to the south of the top of Compass Hill. It is well seen in the ravine above the Coroghon, but cannot be followed farther westward among the basalt-terraces. Yet, though this stratified intercalation is not traceable very far as a band of conglomerate, the same stratigraphical horizon is probably indicated elsewhere by other kinds of sedimentary deposits, to which further reference will be made in the sequel.

The section now described establishes the existence of at least two successive platforms of conglomerate in the volcanic series. Following these platforms along their outcrop, we obtain additional light on their origin, and on the topographical conditions under which they were deposited, and we learn further that other prolonged intervals, which were likewise marked by intercalations of sedimentary material, occurred in the outpouring of the basalts.

Taking first the lower conglomerate of Compass Hill and tracing

it westward, we find that it forms the depression in which the sheltered inlet of Canna Harbour lies. It is exposed along the shores and also in the islands enclosed within the same bay. But it is not traceable farther west, possibly because it seems to sink beneath the level of the sea. To the south-east, though it is there likewise for the greater part concealed under the waves, it rises above them in one or two parts of the coast-line of Sanday, particularly at the Uamh Ruadh or Red Cave, and likewise on a surf-beaten skerry off Ceann an Eilein, the highest part of the Sanday cliffs—a distance of about 1½ mile from Compass Hill. Throughout this space it retains its remarkably coarse character, and is mainly made up of volcanic material.

The numerous sections exposed in Canna Harbour enable us to study the composition and local variations of this curious deposit. On the northern side of the basin, while the lower part of the sedimentary series continues to be an exceedingly coarse volcanic conglomerate, it passes upward into finer conglomerates, tuffs, and shales. In front of Canna House the imbedded blocks are of large size, occasionally as much as 3 or 4 feet in diameter. They are still more gigantic on Eilean a' Bhaird, where I found one to contain 150 cubic feet in the exposed part, the rest being still imbedded in the matrix. As they are generally somewhat rounded, here and there markedly so, most of these stones have probably undergone a certain amount of attrition in water. The great majority of them, and certainly all those of larger size, are pieces of basalt, dolerite, andesite, red bole, etc. Among them huge blocks of amygdaloid and coarsely vesicular lava are specially abundant. Some of these look like pieces of slag torn from the upper surface of lava-streams; others, displaying a highly vesicular centre and a close-grained outer crust, are suggestive of bombs. It is interesting to note here again that the amygdaloidal blocks present their zeolitic infiltrations so precisely like those of the amygdaloids of the plateaux, that it seems reasonable to suppose the carbonate of lime, zeolites, etc. to have been introduced before the blocks were imbedded in the conglomerate.

The whole aspect of this deposit is eminently volcanic. It looks like a vast sheet of lava-fragments swept away from one or more cones of slags and cinders, or from the rugged surface of a lava-stream. Where the vesicles were still empty, the large boulders could be more easily swept along by moving water. But a powerful current must have been needed to transport and wear down into more or less rounded forms blocks of basic lava, many of which must weigh several tons. The large block on Eilean a' Bhaird, for instance, probably exceeds 12 tons in weight.

Besides the obviously volcanic contents of the conglomerate there occur here also, as in the Compass Hill cliffs, abundant pieces of Torridon Sandstone. These stones are notably smaller in size and more perfectly waterworn and even polished than the blocks of lava. Obviously they have travelled farther and have undergone more prolonged attrition.

The matrix of the rock consists essentially of the fine detritus of

basic lavas, probably mingled with true volcanic dust. The coarser parts display only the feeblest indication of stratification; indeed, in a limited exposure the rock might be regarded as a tumultuous agglomerate. But the manner in which the deposit is intercalated with, and sometimes overlies, green tuffs and shales, together with the waterworn condition of its stones, shows that it has not been accumulated in a volcanic chimney, but has been thrown down by some powerful body of water, with probably the co-operation of volcanic discharges.

While the composition of the conglomerate suffices to indicate that it was accumulated at a time when some volcano was active in the immediate neighbourhood, singularly convincing proofs of the work of this vent are to be seen in the form of intercalated sheets of lava. Thus on Eilean a' Bhaird the boulders of the conglomerate are overlain and wrapped round by a sheet of rudely prismatic basalt, with lines of vesicles arranged in the direction of the bedding. A similar relation can be traced along the beach between Canna House and the wooden pier, where successive sheets of basalt have flowed over the conglomerate (see fig. 16, p. 361).

But, besides coarse volcanic detritus, the sedimentary platform represented by the lower conglomerate of Compass Hill includes other deposits of which good sections may be examined all round Canna Harbour. Beds of fine, well-stratified, dull green tuff pass by an admixture of pebbles into fine ashy conglomerate or pebbly sandstone, and by an increase in the proportion of their fine detritus into volcanic mudstone and fine shales. The shales vary from a pale grey or white tone into blackish grey, brown, and black. They are well stratified and are frequently interleaved with layers of fine tuff. The darker bands are carbonaceous, and are not infrequently full of ill-preserved vegetation. Indeed, leaves and stems in a rather macerated condition are of common occurrence in all the shaly layers. Here and there, especially in some ashy shales in front of Canna House, I observed a recognizable *Sequoia*. The mudstones are dull green, close grained, shattery rocks composed of fine volcanic detritus, and pass both laterally and vertically into shales, tuffs, and conglomerates. They suggest showers of fine dust or streams of volcanic mud. They, too, contain fragmentary plants.

It is a noteworthy fact, to which reference has already been made, that the sedimentary intercalations among the Canna basalts generally end upward in carbonaceous shales or coaly layers. The strong currents and overflows of water, which rolled and spread out the coarse materials of the conglomerates, gave way to quieter conditions that allowed silt and mud to gather over the water-bottom, while leaves and other fragments of vegetation were blown or washed into these quiet reaches. Good illustrations of this sequence in the case of the lower conglomerate-zone of Canna may be studied along the shores of Sanday, from the Catholic Chapel eastward. The fine pebbly sandstones, tuffs, and shales, which there overlie the coarse conglomerate, are surmounted by dark brown or black carbonaceous shale with lenticles of matted vegetation that pass

into impure coal. Immediately overlying this coaly layer lies a sheet of prismatic vesicular basalt, followed by another with an exceedingly slaggy texture.

Lenticles of shale and mudstone likewise occur in the heart of the finer parts of the conglomerate, especially towards the top, as may be seen in the section exposed beneath the basalt behind the first cottage west from Canna House. One of the most interesting layers in this section is a seam of tuff varying up to about 2 inches in thickness, which lies at the top of the lenticular band of tuffs and shales, and immediately beneath the band of basalt-conglomerate, on which a basalt, carrying a vesicular band near its bottom, rests. Traced laterally, the dark brown tuff of this seam gradually passes into a series of rounded bodies and flattened shells composed of a colourless mineral which has evidently been developed *in situ* after the deposition of the tuff. Mr. Harker's notes on thin slices made from this band are as follows:—

'This is a rusty brown, dull-looking rock, rather soft and seemingly light, but too absorbent to permit of its specific gravity being tested. The dark brown mass is in great part studded with little spheroidal bodies, $\frac{1}{50}$ to $\frac{1}{16}$ inch in diameter, of paler colour, but the larger ones having a dark nucleus. In other parts larger flat bodies have been formed, as if by the coalescence of the spheroids, extending as inconstant bands in the direction of lamination for perhaps $\frac{1}{2}$ inch, with a thickness of $\frac{1}{16}$ inch or less. The appearance is that of a spherulitic rather than an oolitic structure.

'A slice (6658 A) shows the general mass of the rock to be of an extremely finely divided but coherent substance of brown colour, which can scarcely be other than a fine volcanic dust composed of minute particles of basic glass or "palagonite" compacted together. Scattered through this are fragments of crystals recognizable as triclinic and perhaps monoclinic felspar, green hornblende, augite, olivine (?), and magnetite, usually quite fresh.

'The curious spheroidal and elongated growths already mentioned are better seen in another slide (6658 B), where they occupy the larger part of the field, leaving only an interstitial framework of the brown matrix. The substance of the little spheroids is clear, colourless, and apparently structureless. The centre is often occupied by an irregularly stellate patch of brown colour, and sometimes cracks tend to run in radiating fashion, but these are the only indications of radial structure. The outer boundary is sharply defined, and where the slice is shattered the spheroids have separated from the matrix. The matrix is darker than in the normal rock, being obscured by iron oxide which we may conceive as having been expelled from the spaces occupied by the spheroids. The little crystal-fragments are enclosed in the spheroids as well as in the matrix, but there is no appearance of their having served as starting-points for radiate growths. The flat elongated bodies are like the spheroids, with merely the modifications implied in their different shape.

'The identity of the clear colourless substance seems to be rather

doubtful. It is sensibly isotropic, and of refractive power distinctly lower than that of felspar. These characters would agree with analcime, which is not unknown as a contact-mineral; but it is difficult to understand how analcime, even a lime-bearing variety like that of Plas Newydd,[1] could be formed in abundance from palagonitic material. An alternative supposition, perhaps more probable, is that the clear substance is a glass, modified from its former nature especially by the expulsion of the iron oxide into the remaining matrix. A comparison is at once suggested with certain types of 'knotenschiefer,' but respecting the thermal metamorphism of fine volcanic tuffs there seems to be little or no direct information.

Lenticular interstratifications of shale and mudstone make their appearance even in the coarser parts of the conglomerate,[2] as may be observed on the beach below Canna House where, as shown in fig. 16, some shales and tuffs full of ill-defined leaves are surmounted by a coarse conglomerate. The deposition of this overlying bed of boulders has given rise to some scooping out of the finer strata underneath. Subsequently both the conglomerate and the shales have been overspread by a stream of dolerite, the slaggy bottom of which has ploughed its way through them.

Fig. 16.—*Lava cutting out conglomerate and shale. Shore below Canna House.*

Before discussing the probable conditions under which the group of sedimentary deposits now described was formed, we may conveniently follow the upper conglomerate band of Compass Hill and note the variations in structure and composition which its outcrop presents.

This yellowish conglomerate can be traced along the cliffs for more than a mile, when it descends below the sea-level at the solitary stack of Bod an Stoil. A few hundred yards farther west, what is probably the same band appears again at the base of the precipice overlain by prismatic basalts. But the conglomerate, here only 12 feet thick, is made of much finer detritus which, largely composed of volcanic material, includes small, well rounded and polished pebbles of Torridon Sandstone. Beneath it lies a bed of

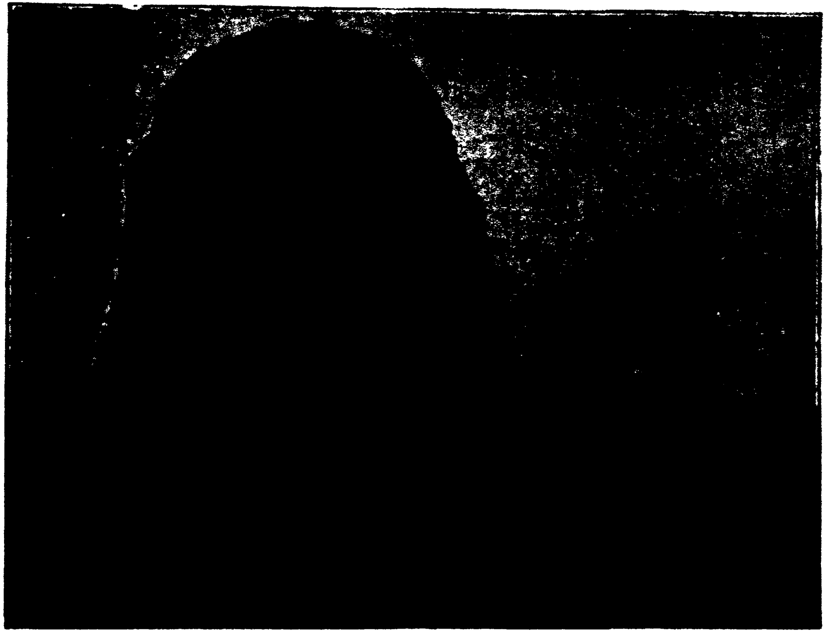
[1] Henslow, Trans. Camb. Phil. Soc. vol. i (1822) p. [illegible]. Harker, Geol. Mag. 1887, p. 414. Mr. W. W. Watts suggests a comparison with the hexagonal bodies figured by Mr. Monckton in an altered limestone from Stirlingshire, Quart. Journ. Geol. Soc. vol. li. (1895) p. [illegible].

shale, with remains of plants, resting immediately on a zeolitic amygdaloid which plunges into the sea. The chief interest of this locality is to be found in the shale which, instead of appearing at the top of the sedimentary stratification, lies at the bottom. I was informed by Mr. A. Thom that leaves had been obtained from this shale, but I was not successful in my search for them. The locality is only accessible by boat, and, as the coast is fully exposed to the Atlantic swell, landing at the place is usually difficult and often impossible.

About $1\frac{1}{4}$ mile still farther west, where a foreshore fronts the precipice of Earnagream at the Camas Tharbernish, a band of intercalated sedimentary material underlies the great escarpment of basalts and rests upon the slaggy sheet with the singular 'aa' surface already referred to. This band not improbably occupies the same platform as the upper conglomerate of Compass Hill. It is only about 7 feet thick, the lower 4 feet consisting of a dull green pebbly tuff or ashy sandstone, with small rounded pieces of Torridon Sandstone, while the upper 3 feet are formed of dark shale with crowded but indistinct remains of plants. Here the more usual order in the sequence of deposition is restored. The shale is indurated and shattery, so that no slabs can be extracted without the use of quarrying-tools.

Rather less than $\frac{1}{4}$ mile towards the south, on the roadside at the gully of Cùl nam Marbh, the basalts enclose a sedimentary interstratification which not improbably lies on the same horizon as those just described along the northern shore. The relations of the rocks at this locality are shown in fig. 17. A remarkably slaggy basalt (*a*) rises into a hummock against which [illegible] fine granular tuffs (*b*), whereof only a few inches are visible, that pass up into a thin band of dark shale (*c*), including a layer of pebbly ferruginous tuff, with small rounded [illegible]-like masses of basalt, basic [illegible] bole, limonite, etc. At the top of this shale an irregular parting of coaly material (*d*) lies immediately under the slaggy base of the succeeding basalt (*e*). It will be observed that this upper lava cuts out the shale and thus comes to rest directly upon the lower sheet. At the point where it begins to descend it has caught up and enclosed a small tree-stump (*d'*) which stands upright on the coaly parting and shale. This stump, at the time of my visit, measured 5 inches in height by 3 inches in breadth: it had been thoroughly charred and was crumbling away on exposure, but among the pieces which I took from it sufficient trace of structure can be detected with the microscope to show the tree to have been a conifer.

Fig. 17.—*Section of shales, tuffs, and a coniferous stump lying between two basalt-sheets. Cùl nam Marbh, Canna.*



Dùn Mòr, Sanday. (From a photograph by Miss Thom, of Canna.)

We have here another instance of the deposition of volcanic dust and fine mud in a pool that filled a hollow in the lava-field. Again we see that the closing act of sedimentation was the washing of vegetable matter into the pool, which was finally buried under another outflow of basalt.

It is on the southern coast of the isle of Sanday that the higher intercalations of sedimentary material among the basalts are most instructively displayed. At the eastern end of this island, as already stated, the lowest and coarsest conglomerate is visible on a skerry immediately south of the headland of Ceann an Eilein. It doubtless underlies the Sanday cliffs, but is not there visible, for the basalts descend below sea-level. These volcanic sheets have a slight inclination westward; hence as we proceed in that direction we gradually pass into higher parts of the series. In the Creag nam Faoileann (Seamews' Crag) and the gully that cuts its eastern end, likewise in the two singularly picturesque stacks of Dùn Mòr and Dùn Beag (Big and Little Gull Rocks), which here rise from the foreshore, two distinct platforms of detrital material may be noticed among the basalts. Both of these can be well seen on Dùn Mòr, which is represented in Pl. XVII. The lower band, 4 or 5 feet thick, is here a rather coarse conglomerate, which lies upon a sheet of scoriaceous basalt that extends up to the base of the Creag nam Faoileann. It is directly overlain by another basalt, about 30 feet thick, which dips seaward and forms a broad shelving platform, whereon the tides rise and fall. On this stack a second coarse conglomerate, about 10 feet thick, forms a conspicuous band about a third of the height from the bottom; it is composed mainly of well-rounded blocks of various lavas up to 18 inches or more in diameter, but it contains also pieces of Torridon Sandstone. It is covered by about 60 feet of basalt, which towards the base is somewhat regularly columnar, but passes upward into the wavy, starch-like, prismatic structure.

If now we trace these two intercalated zones of conglomerate along the shore, we find that they both rapidly change their characters and disappear. The lower, though formed of coarse detritus under the Dun Mòr, passes on the opposite cliff, in a space of not more than 60 yards, into fine tuff and shale, about 6 feet thick, which become carbonaceous at the top, where they are overlain by the next basalt. A hundred yards to the east the band likewise consists of tuffs and ashy shales, which underlie the basalts on the Dùn Beag, and again show the usual coaly layers at the top. On the eastern side of the gully in the coast, about 150 yards north-east of Dùn Mòr, the same band is reduced to not more than 3 feet in thickness, consisting chiefly of fine conglomerate, wherein well waterworn pebbles of Torridon Sandstone and epidotic grit appear among the predominant volcanic detritus. This conglomerate is surmounted by a few inches of dark carbonaceous mudstone or shale. Rough slaggy basalts lie above and below the band.

The upper conglomerate dies out, both eastward and westward, in the cliff opposite the Dun Mor, dwindling down at last to

merely a few pebbles between the basalts. It lies in a kind of channel or hollow among these lavas, which in an east-and-west direction cannot be more than about 65 yards broad.

Probably still higher in the series of basalts is another intercalation of sedimentary layers which may be seen in the little bay to the east of Tallabric, rather more than a mile to the west of the Creag nam Faoileann. It rests upon a coarsely slaggy amygdaloid, and is from 6 to 10 feet in thickness. The lower and larger part of the deposit consists of greenish pebbly sandstone and fine conglomerate, largely composed of basaltic detritus, but including abundant well-smoothed and polished pebbles of Torridon Sandstone, green grit, quartzite, etc. The stones vary from mere pea-like pebbles up to pieces 2 or 3 inches long, the largest being generally fragments of slag and amygdaloid which are less waterworn than the sandstones and other foreign ingredients. The uppermost 2 or 3 feet of the intercalation consist of dark carbonaceous mudstone or shale, made up in large measure of volcanic detritus, which may have been derived partly from eruptions of fine dust, partly from subaerial disintegration of the basalt-sheets. Some layers of these finer strata are full of remains of much macerated plants.

Other thin coaly intercalations have been observed among the basalts of Canna, some of which may possibly mark still higher horizons than those now described. But, confining our attention to the regular sequence of intercalations exposed along the Sanday coast, we find at least four distinct platforms of interstratified sediment among the plateau basalts of this district. Each of these marks a longer or shorter interval in the outflow of lava, and points to the action of moving water over the surface of the lava-fields.

We may now consider the probable conditions under which this intervention of aqueous action took place. The idea that the sea had anything to do with these conglomerates, sandstones, and shales may be summarily dismissed from consideration. The evidence that the basalt-eruptions took place on a terrestrial surface is entirely convincing, and geologists are now agreed upon this question.

Excluding marine action, we have to choose among forms of fresh water—between lakes on the one hand and rivers on the other. That the agency concerned in the transport and deposition of these strata was that of a river may be confidently concluded on the following grounds:

1. The large size and rolled shapes of the boulders in the conglomerates. To move blocks several tons in weight, and not only to move them but to wear them into more or less rounded forms, must have required the operation of strong currents of water. The coarse detritus intercalated among the basalts is quite comparable to the shingle of a modern river, which descends with rapidity and in ample volume from a range of hills.

2. The evidence that the materials of the conglomerates are not entirely local, but include a marked proportion of foreign stones,

The proofs of transport are admirably exhibited by the pieces of Torridon Sandstone, epidotic grit, quartzite, and other hard rocks, none of which occur *in situ* except at some distance from Canna. These stones are often not merely rounded, but so well smoothed and polished as to show that they must have been rolled along for some considerable time in water.

3. The lenticular character and rapid lithological variations of the strata, both laterally and vertically. The coarse conglomerates die out as they are followed along their outcrop and pass into finer sediment. They seem to occur in irregular banks, which may not be more than 200 feet broad, like the shingle-banks of a river. The coarser sediment generally lies in the lower part of the sedimentary group. But cases may be observed, such as that shown in fig. 16, p. 361, where the fine sediment laid down upon the bottom conglomerate has subsequently been overspread by another inroad of coarse shingle. Such alternations are not difficult to understand, if they are looked upon as indicating the successive floods and quieter intervals of a river.

For these reasons I regard the platforms of sedimentary material intercalated among the basalts of Canna and Sanday as the successive flood-plains of a river which, like the rivers that traverse the lava-deserts of Iceland, flowed perhaps in many separate channels across the basalt-fields of the Inner Hebrides and was liable to have its course shifted from time to time by fresh volcanic eruptions. That this river came from the east or north-east and had its source among the western highlands of Inverness-shire may be inferred from the nature of the stones which it has carried for 30 miles or more along its bed. And that it crossed in its course the tract of Torridon Sandstone, of which a portion still remains in Rum, is manifest from the abundance of the fragments of that formation in the conglomerates.

With the remarkable exception of the section on Dun Beag, to be immediately referred to, no trace of any eroded channel of this river through the lavas of the great volcanic plain has been preserved. Possibly frequent invasions of its bed by streams of basalt from different vents hindered it from remaining long enough in one course to erode anything like a gorge or cañon. But, in any case, the main channel of the river probably lay rather to the east of the present islands of Canna and Sanday, on ground which is now covered by the sea. The banks or sheets of boulder-conglomerate undoubtedly show where its current swept with great force over the lava-plain, but the manner in which these coarser materials are so often covered with fine silt suggests that the sedimentary materials now visible were deposited rather on the low grounds over which the stream rushed in times of flood. Pools of water would often be left after such inundations, and in these depressions silt would gradually accumulate, partly carried in suspension by the river, partly washed in by rain, while drift-wood that found its way into these eddies, and leaves blown into them from the trees and shrubs of the surrounding country, would remain for some time afloat, and would be the last of the detritus to sink to the bottom. Hence, no doubt,

the carbonaceous character of the hardened silt in the upper part of each intercalation of sediment.

If we were to look upon the volcanic materials in the conglomerates as derived from the subaerial disintegration of the fields of basalt, we should be compelled to admit a very large amount of erosion of the surface of the volcanic plain during the period when the river flowed over that tract. It would be necessary to suppose not only that there was a considerable rainfall, but that the differences of temperature, either from day to night or from summer to winter, were so great as to split up the lavas at the surface in order to provide the river with the blocks which it has rolled into rounded boulders. I do not think, however, that such a deduction would be sound. If we compare the materials that have filled up the eruptive vent at the eastern end of Canna with the great majority of the blocks in the coarse conglomerates, we cannot fail to note their strong resemblance. The abundance of lumps of slaggy lava in the river-shingle corresponds with their predominance in the agglomerate of the vent. The boulders of basalt, dolerite, and andesite which crowd the conglomerates need not have been derived from the action of atmospheric waste on the lava-fields, but might quite well have been mainly supplied by the demolition of one or more volcanic cones of fragmental materials.

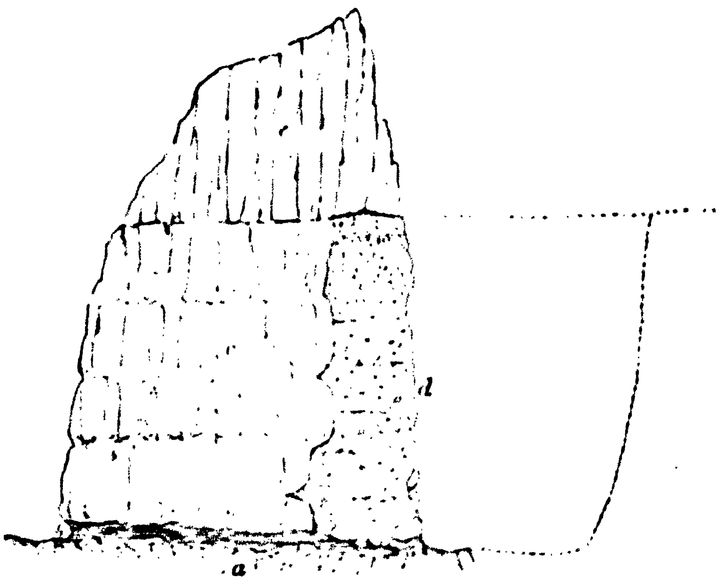
That such has really been the chief source of the blocks in the conglomerates I cannot doubt. At the eastern end of Canna we actually detect a volcanic cone partly washed down and overlain by a pile of river-shingle. There were probably many such mounds of slag and stones along lines of fissure all over the lava-fields. The river in its winding course might come upon one cone after another, and during times of flood, or when its waters burst through any temporary barrier created by volcanic operations it would attack the slopes of loose material and sweep their detritus onward. At the same time, the current would carry forward its own natural burden of far-transplanted sediment, and hence on its old flood-plains, buried and preserved under sheets of basalt, we find abundant pebbles of the old Highland rocks which it had borne across the whole breadth of the basaltic lowland.

But the destruction of volcanic cones was probably not the only source of the detritus that now forms the conglomerates of Canna and Sanday. I have shown that these conglomerates pass laterally into tuffs, and are sometimes underlain, sometimes overlain, with similar material. It is quite obvious that their deposition was contemporaneous with volcanic action in the immediate neighbourhood, and that at least part of their finer sediment was obtained directly from volcanic explosions. In wandering over the coast-sections of these remarkably coarse deposits, I have been impressed with the enormous size of many of the stones, their resemblance to the ejected blocks of the agglomerate and the distinction that may sometimes be made with more or less clearness between their rather angular forms and the more rounded and somewhat waterworn aspect of the other boulders. It seems to me not improbable that

some of the remarkably coarse masses of unstratified conglomerate in Canna Harbour consist largely of ejected blocks from the adjacent vent.

The only instance which I have observed of erosion of the basalts contemporaneous with the operations of the river that spread out this conglomerate is to be found in the striking stack of Dùn Beag already alluded to.[1] This extraordinary monument of geological history forms an outlying obelisk which rises from the platform of the shore to a height of about 70 feet. Seen from the south-west it appears to consist entirely of bedded basalt resting on some stratified tuff and shale which intervene between these lavas and that of the broad platform of basalt on which the obelisk stands.

Fig. 18.—*Section of the eastern front of the Dùn Beag.*



a. Very slaggy amygdaloidal basalt.
b. Shales and tuff
c. Slaggy and jointed basalts
d. Conglomerate
e. Prismatic basalt

The dotted lines indicate the supposed form of the ravine

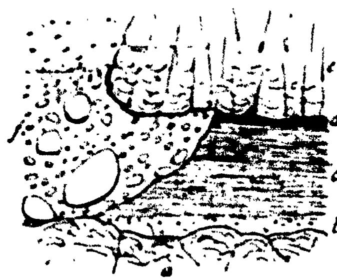
On that side it presents no essential difference from the structure of ... ...n Mor on the west, save that the lower conglomerate of ... is here represented by fine sediment, and the upper ... wanting. The general aspect of this south-western

... of rock is referred to by Macculloch in his account of Canna. ... in pl. xx. fig. 3 in his work already cited. But neither his ... nor his drawing conveys any idea of the real structure of the rock.

front of the stack is shown in Pl. XVIII. If, however, we approach the rock from the coast-gully to the north, we form a very different impression of its structure. It then appears to consist chiefly of conglomerates with a capping of basalt on the top. It is not until a close scrutiny is made of the eastern and western faces of the column that the true structure and history of this singular and striking piece of topography become apparent.

On the eastern front the section represented in fig. 18, p. 367, is exposed. At the bottom, forming the pediment of the column, lies a sheet of slaggy and vesicular or amygdaloidal basalt (*a*), which shelves gently in a south-westerly direction into the sea. The lowest band (*b*) in the structure of the stack is a thin group of lilac, brown, and green shale and volcanic mudstone or tuff, which encloses pieces of coniferous wood, and becomes markedly carbonaceous in its uppermost layers. Above these strata on the southern front comes the pile of bedded basalts (*c*) with their slaggy lower and upper surfaces. But as we follow them round the eastern side we find them abruptly cut off by a mass of conglomerate (*d*). That the vertical junction-line is not a fault is speedily ascertained. The lower platform of slaggy basalt runs on unbroken under both the shales and the conglomerate. Moreover, the line of meeting of this conglomerate with the basalts that overlie the shales is not a clean-cut straight wall, but displays projections and recesses of the igneous rocks round and into which the materials of the conglomerate have been deposited. The pebbles may be seen filling up little crevices, passing under overhanging ledges of the basalts, and sharply truncating lines of scoriaceous structure in these rocks. The same relations may be observed on the western front of the stack. There the ashy shales and tuffs are sharply cut out by the conglomerate which wraps round and underlies a projecting cornice of the slaggy bottom of the basalt that rests on the stratified band (fig. 19).

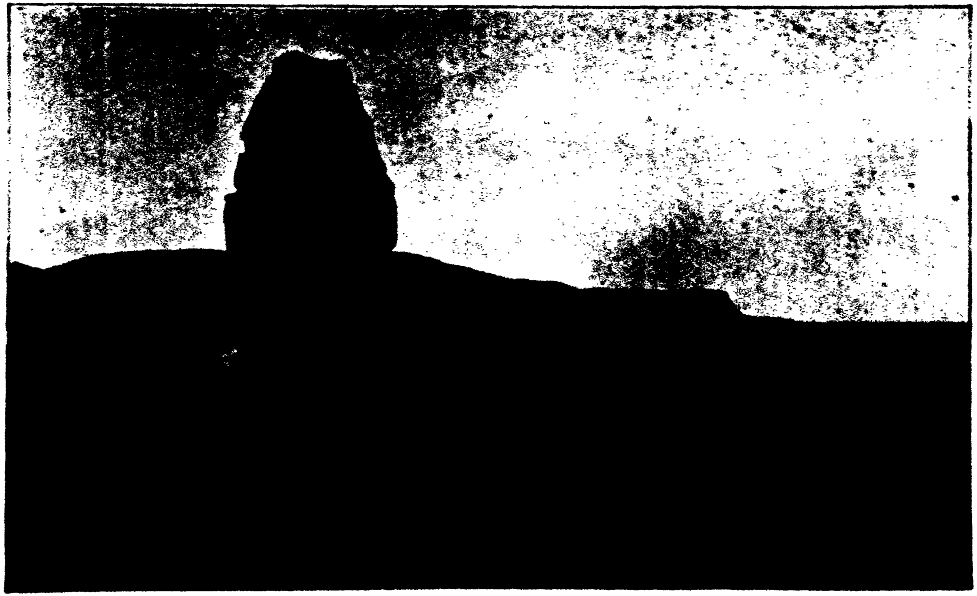
Fig. 19. *Enlarged section on the western side of the Dùn Beag.*



a, amygdaloid; *b*, tuff; *c*, ashy shales; *d*, layer of coaly shale; *e*, amygdaloidal basalts; *f*, conglomerate.

The conglomerate is rudely stratified horizontally, its bedding being best shown by occasional partings of greenish sandstone. It consists of well-rounded, polished, and water-worn stones, chiefly of members of the volcanic series,—basalts, and dolerites, both compact and amygdaloidal or slaggy,—but with a conspicuous admixture of Torridon Sandstone, gneiss, grey granite, grit, and different schists. The coarsest part of the deposit lies towards the bottom, where the volcanic blocks are sometimes 6 and 8 feet in diameter. Some of these large masses

DÙN BEAG, SANDAY, SEEN FROM THE SOUTH-WEST.
(From a photograph by Miss THOM, of Canna.)



DÙN BEAG, SANDAY, SEEN FROM THE NORTH. THE ISLAND OF RUM IN THE DISTANCE.
(From a photograph by Miss Thom, of Canna.)

may have originally fallen from the basalts against which the conglomerate now reposes. The far-transported stones are also of considerable size, pieces of granite and gneiss frequently exceeding a foot in length. The well-rounded pebbles of foreign materials have been washed into the interstices between the large volcanic blocks.

It is, I think, tolerably clear that the wall of basalt against which this conglomerate has been laid down is one of erosion. The beds of basalt have here been trenched by some agent which has likewise scooped out the soft underlying shales, and even cut them away from under their protecting cover of basalt, as shown in figs. 18 & 19. There can be little hesitation in regarding this agent as a watercourse which for some considerable interval of time continued to dig its channel through the hard basalts. There is not room enough between the basalt wall of the Dùn Beag and the opposite cliffs of the shore (where no trace of this conglomerate is to be seen) for any large stream to have found its way. I do not, therefore, seek to identify this relic of an ancient waterway with the channel of the main river which deposited the conglomerate-bands of Canna and Sanday. More probably it was either a mere torrential chasm or a tributary stream, draining a certain part of the volcanic plateau and allowed to retain its channel long enough to be able to erode it to a depth of nearly 50 feet. Even it had reached down through the underlying tuffs to the slaggy basalt below, but before it had made any progress in that sheet its operations were brought to an end at this locality by the floods that swept in the coarse shingle and by the subsequent stream of basalt, of which a mere outlying fragment now forms the upper third of the stack (c in fig. 18).

The ravine or gully of the Dùn Beag probably lay within reach of the floods of the main river, as may be inferred from the number and size of the far-transported rocks in its conglomerate. The conditions of deposition remained little changed during the process of filling up with detritus, except that the largest blocks of rock were swept into the chasm in the earlier part of its history, while much smaller and more waterworn shingle was introduced towards the close.

Denudation, which has performed such marvels in the topography of the West of Scotland since older Tertiary time, has here obliterated every trace of this ancient gully, save the little fragment of one of the walls which survives in the stack of Dùn Beag. When in the course of centuries this picturesque obelisk shall have yielded to the action of the elements, the last leaflet of one of the most interesting chapters in the geological history of the Inner Hebrides will have been destroyed.

The question naturally arises, What was the subsequent history of the river which has left so many records of its floods entombed among the basalts of Canna and Sanday? In particular, can any connexion be traced or plausibly conjectured between it and the river-bed preserved under the Scuir of Eigg?

In dealing with this subject, though the evidence is admittedly

scanty, we are not left wholly to conjecture. A consideration of the general topographical features of the wide region of the Inner Hebrides, from the beginning of the volcanic period onward, will convince us that, in spite of the effects of prolonged basalt-eruptions, the persistent flow of the drainage of the Western Highlands must have taken a westerly direction. It was towards the west that the low grounds lay. Though the long and broad valley which stretched northwards from Antrim between the line of the Outer Hebrides and the West of Scotland was gradually buried under a depth of 2000 or 3000 feet of lava, the volcanic plain that overspread it probably remained even to the end lower than the mountainous Western Highlands. Hence the rivers, no matter how constantly they may have had their beds filled up and may have been driven into new channels, would nevertheless always seek their way westward into the Atlantic.

On Canna and Sanday we have the traces of a river which poured its flood-waters across the lava-fields in that part of the volcanic region, while the basalts were still from time to time streaming from vents and fissures. Not more than 14 miles south-east stands the Scuir of Eigg, with its buried river-channel and its striking evidence that this river likewise flowed westward, though at a far later time, when the basalt eruptions had ceased and the volcanic plain had been already deeply trenched by erosion, but when the subterranean fires were not yet quenched.

When one reflects upon the enormous denudation of this region, to which further reference will be made in the sequel, one is not surprised that many connecting links should have been effaced. The astonishment rather arises that so continuous a story can still be deciphered. Even, however, had the original record been left complete, it would have been exceedingly difficult to trace the successive mutations of a river-channel during long ages of volcanic eruptions. Such a channel would have been concealed from view by each lava-stream that poured into it, and would not have been again exposed save by the very process of erosion that destroys while it reveals.

While, therefore, there is not and can never be any positive proof that in the fluviatile records of Canna, Sanday, and Eigg successive phases are registered in the history of one single stream, I believe that this identity is highly probable. It was a river which rose among the mountains of Western Inverness-shire, and had already taken its course to the sea before any volcanic eruptions had begun. It continued to flow westward across the lava-floor that gradually spread over the plains. Its channel was constantly being filled up by fresh streams of basalt, or deflected by the uprise of new cinder-cones. But, fed by the Atlantic rains, it maintained its seaward flow until the general subsidence which carried so much of the volcanic plain below the sea. Yet the higher part of this ancient watercourse is no doubt unsubmerged, still traversing the schists of the Western Highlands as it has done since older Tertiary time. It may, perhaps, be recognised in one of the glens which

carry seaward the drainage of the districts of Morar, Arisaig, or Moidart.

When one scans the great precipice on the western side of the island of Eigg, which displays a transverse section across the pitchstone-lava with its buried river-bed and the basalt-plateau underneath, there seems no chance of any further westward trace of this pitchstone being ever found. The truncated end of the Scuir looks from the top of the cliff out to sea, and the progress of denudation might have been supposed to have effectually destroyed all evidence of the continuation of the rock in a westerly direction. Some years ago, however, my friend Prof. Heddle, while cruising among the Inner Hebrides, landed upon the little uninhabited islet of Hysgeir, which rises out of the open sea, some 18 miles to the westward of Eigg. He at once recognized the identity of the rock composing this islet with that of the Scuir, and in the year 1892 published a brief account of this interesting discovery.[1]

I have myself been able to land on Hysgeir in two successive summers, and can entirely confirm Prof. Heddle's identification. The islet stands on the eastern edge of the submarine ridge which, running in a north-easterly direction, culminates in the island of Canna. Hysgeir is a mere reef or skerry, of which the top rises only 38 feet above the Ordnance datum-level. Its surface is one of bare rock, save where a short but luxuriant growth of grasses has found root on the higher parts of two or three of its ridges, and on the old storm-beach of shingle which remains on the summit. The rock undulates in long low swells that run in a general direction 20° to 45° west of north, and are separated by narrow channels or hollows. The place is a favourite haunt of gulls, terns, eider-ducks, and grey seals, and is used by the proprietor of Canna for the occasional pasturage of sheep or cattle. So numerous are the sea-fowl during the breeding-season that the geologist, intent upon his own pursuits, may often tread unawares on their nests, while he is the centre of a restless circle of white wings and anxious cries.

The pitchstone of Hysgeir, like that of Eigg, is columnar, the columns being irregularly polygonal and varying from 3 to 10 inches in diameter. They are packed so close together that the domes of rock on which their ends appear look like rounded masses of honeycomb. They may here and there be observed to be arranged radially, with their ends at right angles to the curved exterior of the ridges, as if this external surface represented the original form of the cooled pitchstone, and were not due to mere denudation. There can be no doubt, however, that the island has been well ice-worn.

At the north-western promontory a beautiful example of fan-shaped grouping of columns may be observed on a face of rock which descends vertically into the sea. Here, too, is almost the only section on which the sides of the columns may be examined, for, as

[1] Appendix C to 'A Vertebrate Fauna of Argyle and the Inner Hebrides,' by J. A. Harvie-Brown and Thomas E. Buckley, p. 248.

a rule, it is merely their ends on the rounded domes which are to be observed, and which everywhere slip under the waves. The columns in a cliff from 15 to 20 feet high show the slightly wavy, starch-like arrangement so often to be met with among the plateau-basalts.

The rock presents a tolerably uniform texture throughout, though in some parts it is blacker, more resinous, and less charged with porphyritic enclosures than in the general body of the rock. Large fresh felspars are generally scattered through it. To the naked eye it reproduces every feature of the pitchstone of the Scuir of Eigg.

A microscopic examination completes our recognition of the identity of these two rocks. Mr. Harker has examined a thin slice prepared from the Hysgeir pitchstone, and remarks regarding it that 'the large felspars are not the only porphyritic element. The microscope shows the presence also of smaller imperfect crystals of augite, very faint green in the slice, and small grains of magnetite. The felspars have been deeply corroded by the enveloping magma, and irregular included patches of the groundmass occupy nearly half the bulk of some of the crystals. This latter feature is seen especially in some of the larger crystals, which seem to be sanidine. They are, for the most part, apparently simple crystals, but in places there is a scarcely defined lamellar twinning, or, again, small patches not extinguishing with the rest; so that we are probably dealing with some perthitic intergrowth on a minute scale.'[1]

'Rather smaller felspar-crystals are rounded by corrosion, but lack the inclusions of groundmass; these have albite- and sometimes pericline-lamellation, and may be referred to oligoclase-andesine. The groundmass of the rock is a brown glass with perlitic cracks, enclosing very numerous microlites of felspar about ·001 inch in length (6610). The rock is probably to be regarded as a dacite rather than a rhyolite, and thus agrees with Mr. Barker-North's analysis of the Eigg pitchstone.'[2] There is no trace of any conglomerate *in situ* like that under the Scuir of Eigg, nor of any other rock, aqueous or igneous. As the pitchstone everywhere slips under the sea, its geological relations are entirely concealed.

The great variety of materials met with in the form of boulders on Hysgeir is a testimony to the transport of erratics from the neighbouring islands and the mainland during the Glacial Period. The most abundant rock in these boulders is Torridon Sandstone, derived, no doubt, from the hills of Rum; but there occur also various kinds of schist, gneisses, quartzites, granites, porphyries, probably from the west of Inverness-shire, as well as pieces of white sandstone, probably Jurassic, which may have come from Eigg.

That the pitchstone of Hysgeir is a continuation of that of the Scuir may be regarded as highly probable. If not a continuation, it must be another stream of the same kind, and doubtless of the same date. If it be regarded as probably a westward prolongation of

[1] Comp. Prof. Judd's remarks on the Scuir of Eigg rock, Quart. Journ. Geol. Soc. vol. xlvi. (1890) p. 380.

[2] *Ibid.* p. 379.

the Eigg rock, and if it is about as thick as that mass at the western end of the Scuir, then its bottom lies 200 or 300 feet under the waves. The river-channel occupied by the Eigg pitchstone undoubtedly sloped from east to west. The position of Hyskeir, 18 miles farther west, indicates a further fall in the same direction at the rate of perhaps as much as 35 feet in the mile.[1] Unfortunately, however, as no trace of the river-bed can now be seen on this island, any statement in regard to its prolongation must rest on mere conjecture.

IV. The Basic Sills.

One of the most characteristic structural features in the basalt-plateaux of North-western Europe is the number, thickness, and extent of the basic sills or intrusive sheets which accompany these piles of volcanic material. As I have formerly shown,[2] the sills, though they may be observed in any part of the basalt series, are more particularly developed at its base, and are notably interpolated among the Secondary formations which underlie it. In addition to the examples which I have already described, the following localities are here cited as affording excellent illustrations of the more characteristic features of intrusive sheets.

The eastern coast of Skye has been classic ground for this part of volcanic geology since the publication of Macculloch's descriptions and diagrams. From the mouth of Loch Sligachan to Rudha Hunish, at the northern end of the island, a series of sills may be traced, sometimes crowning the cliffs as a columnar mural escarpment, sometimes burrowing in endless veins and threads through the Jurassic rocks. The horizontal distance to which this band of sills extends in Skye is not far short of 30 miles. But it stretches beyond the limits of this island. It forms the group of islets which prolong the geological structure and topographical features of Trotternish for 4 miles farther to the north-west. It reappears 10 miles still farther on in the Shiant Isles. Thus its total visible length is fully 40 miles. As a display of intrusive basic igneous rocks it ranks next to the Great Whin Sill among the British instances of this tectonic type.

The larger sheets in this belt have certain characteristic features. They are generally somewhat coarsely crystalline ophitic dolerites or diabases, and exhibit the persistent uniformity of composition and structure so characteristic of intrusive sheets and dykes. They display in many cases a regularly prismatic arrangement, the columns being much thicker and longer than those of the basalts of the plateaux or those of the dykes and veins. The regularity of this structure is well shown in the great sill of which the Kilt Rock is one of the most noted portions (fig. 20, p. 374). But the most astonishing example is that which forms the Garbh Eilean of the Shiant Isles, where the sill presents to the sea a vertical columnar

[1] Rep. Brit. Assoc. 1894 (Oxford meeting), p. 663.
[2] Quart. Journ. Geol. Soc. vol. xxvii. (1871) p. 295; Trans. Roy. Soc. Edinb. vol. xxxv. (1888) p. 111.

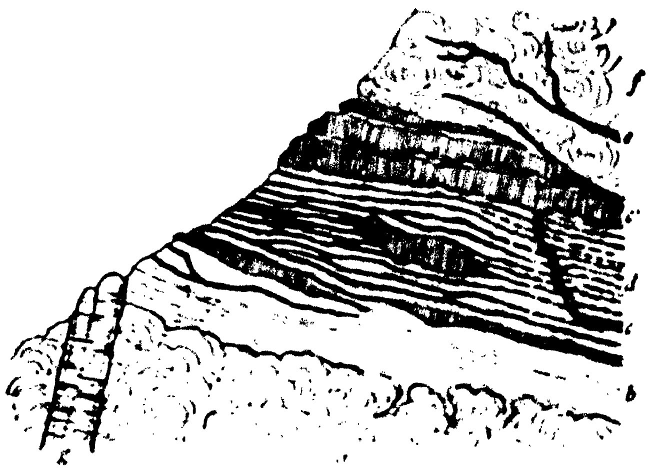
Fig. 20.—*Columnar sill intrusive in Jurassic strata east of Kilmartin, Trotternish, Skye.*

[The high ground on the left is a portion of the basalt-plateau to the north of the well-known Quiraing.]

wall 500 feet high. Though I could not certainly trace any single column continuously from bottom to top of the precipice, many of them must be at least 300 or 400 feet long. No other sill in the British Islands forms such a noble escarpment as this.

In contrast to such enormous thicknesses of intrusive material, instances may be culled from the same belt of sills where the molten rock has been injected in thin cakes and mere threads into the Jurassic sandstones and shales, or into the shales and coals intercalated among the plateau-basalts. Thus, on the cliff immediately north of Ach na Hannait, between Loch Sligachan and Portree Bay, the section which is represented in fig. 21 may be seen.

Fig. 21.—*Section of thin intrusive sheets and veins in carbonaceous shales lying among the plateau-basalts. Cliff north of Ach na Hannait, between Portree Bay and Loch Sligachan.*



At the base lies a vesicular dolerite with a slaggy upper surface (*a*). Next comes a zone of sedimentary material about 5 or 6 feet thick, the lower portion consisting of an impure coal, which passes towards the right hand into brown and grey carbonaceous shale with plant-remains (*b*). This coaly layer has been already alluded to as probably lying on the same horizon with the coal of Portree. Traced northward, it is found to have a bed of fine tuff beneath it, and sometimes a volcanic breccia or conglomerate. It fills up rents in the underlying slaggy lava, and was undoubtedly deposited upon the cooled surface of that rock. Immediately above this lower band the black carbonaceous shale (*d*) which follows has been invaded by an extraordinary number of thin cakes or sills, and also by veins or threads of basalt. For a thickness of 2 or 3 feet the band consists mainly of these intrusions, which, in the form of a fine

grey basalt, vary from less than 1 to 3 or 4 inches in thickness. They are separated by thin partings of coaly shale, and as they tend to break up into detached nodule-like portions, especially towards the right hand of the section represented in fig. 21, they might, on casual inspection, be easily mistaken for nodules in the dark shales. Somewhat later in the time of intrusion are veins of basalt which, as at *c*, break across the nodular sills, and sometimes expand into thicker beds (*c'*).

I have never seen such a congeries of minute sills among the Tertiary basalt-plateaux as that here exhibited. In a space of about 3 feet of vertical height there must be more than a dozen roughly parallel cakes of intrusive rock. Veins (*e*) run up from the chief band of eruptive material into the overlying finely vesicular basalt (*f*). The dyke (*g*) is probably the youngest rock in the section.

The amount of contact-metamorphism effected even by such thick sills as those of Trotternish and Shiant is much less than might be expected. It seldom goes beyond a mere induration of the strata for a few yards, often only for a few inches from the surface of junction. In the Shiant Isles the shales on which the sills rest have undergone a remarkable alteration. They have been greatly indurated, and have acquired a globular or botryoidal structure. The spheroidal aggregates vary from not more than a line to more than half an inch in diameter, and appear on the surface as dark, irregularly grouped, pea-like aggregates. This structure is perhaps best developed immediately under the thick sill that forms Eilean Muirhi.[1]

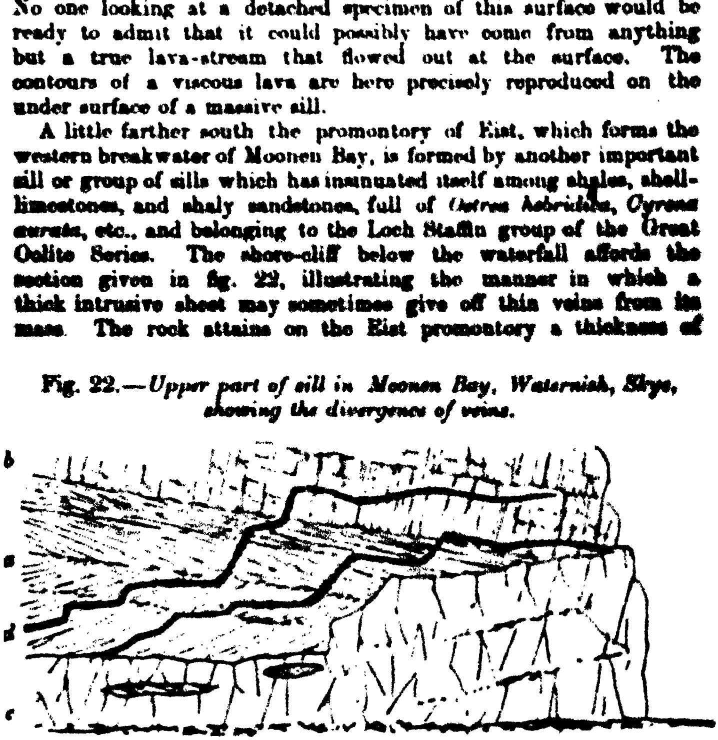
On the western side of Skye, owing to greater local subsidence of the basaltic plateau, the base of the volcanic series is seldom seen, and hence the platform of sills is for the most part concealed under the sea. But where at one or two points the Jurassic strata are brought up to the light of day, they have carried with them their intrusive sheets of basic rock. Thus, at the mouth of Dunvegan Loch, the islets of Mingay and Clett form parts of a sill which rests on shell-limestones full of oysters (*Ostrea hebridica*), referable to the Loch Staffin group of the Great Oolite Series. This rock, when observed from a little distance, presents the usual regularly prismatic or columnar structure so well developed among the Trotternish sills, but on a closer view shows this structure much less distinctly. It is an olivine-dolerite of medium and fine texture, which in thin slices displays under the microscope a distinctly ophitic structure, the abundant light-brown augite enclosing the striated felspars. Its lowest portion, from 3 to 7 or 8 inches upward from the bottom, is much closer-textured than the rest of the rock and is finely amygdaloidal. Its vesicles are in many cases drawn out to a length of 3 or 4 inches, and the zeolites which now fill them look like parallel annelid tubes or stems of *Lithostrotion*. It is noteworthy also that the elongation of the vesicles has

[1] Macculloch, 'Description of the Western Islands,' vol. i. (1819) p. 441.

sometimes taken place at right angles to the surface of contact with the underlying strata. But the most remarkable feature in this sill is the surface which it presents to the oyster-beds on which it rests. The fine-grained dark dolerite has there assumed the aspect of a sheet of iron-slag, with a smooth or wrinkled, twisted, ropy surface, which displays fine curving flow-lines. No one looking at a detached specimen of this surface would be ready to admit that it could possibly have come from anything but a true lava-stream that flowed out at the surface. The contours of a viscous lava are here precisely reproduced on the under surface of a massive sill.

A little farther south the promontory of Eist, which forms the western breakwater of Moonen Bay, is formed by another important sill or group of sills which has insinuated itself among shales, shell-limestones, and shaly sandstones, full of *Ostrea hebridica*, *Cyrena curata*, etc., and belonging to the Loch Staffin group of the Great Oolite Series. The shore-cliff below the waterfall affords the section given in fig. 22, illustrating the manner in which a thick intrusive sheet may sometimes give off thin veins from its mass. The rock attains on the Eist promontory a thickness of

Fig. 22.—*Upper part of sill in Moonen Bay, Waternish, Skye, showing the divergence of veins.*



a. False-bedded shaly sandstone; b. Shell-limestone (Great Oolite Series); c. Dolerite-sill; dd. Veins proceeding from the sill. Length of section = about 5 yards.

probably at least 100 feet, where it is thickest and undivided. But the two main sheets, or branches of one great sheet, on this peninsula have probably an united depth of more than 300 feet. Landwards the rock splits up and encloses cakes of the Jurassic strata. It possesses the usual prismatic structure and doleritic composition. In Moonen Bay, as shown in fig. 22, it presents a banded structure, marked especially by alternation of lines of amygdules and layers of more compact and solid dolerite, with occasional enclosed cakes of baked shale or sandstone. Its upper surface is somewhat uneven, and from it are given off narrow, wavy, ribbon-like veins (*d*), from

less than 1 to 3 inches or more in width, which keep in a general sense parallel to the top of the sill, but at a distance of a few inches or feet from it. The sill becomes as usual fine-grained towards the contact, the shales and sandstones being indurated and the limestone marmorized.

Still farther south the bottom of the basalt-plateau is again reached in the Sound of Soa, where the volcanic pile has been poured out over the upturned edges of the Torridon Sandstone. It is hardly possible to exaggerate the wild confusion of sills, dykes, and veins which have been injected among the rocks at and on both sides of the unconformability. Endless sheets of basalt and dolerite have forced their way between the bedded basalts and the sandstones, while across the whole rise vast numbers of dykes and veins. Narrow, black, wavy ribbons of basic material cross many of these veins, while the later north-western dykes cut sharply through everything older than themselves. As a natural section for the study of the phenomena of intrusion in many of their most characteristic phases, I know no locality equal to the northern coast-line of the Sound of Soa, unless it be the cliffs of Ardnamurchan. But the Skye cliffs, though less imposing than those of the great Argyleshire headland, have this great advantage, that instead of being exposed to the full roll of the open Atlantic, they form the margin of a comparatively sheltered strait, and can thus be conveniently examined.

There is one remaining locality in Skye to which I wish to direct attention, since it displays certain phenomena of sills which I have never seen so perfectly exhibited elsewhere. It lies on the western side of the promontory of Sleat, about midway between the basalt-plateau of Strathaird and that of Eigg, and about 8 or 9 miles in a direct line from either. The basalts cannot be proved to have once stretched continuously between Eigg and Strathaird, and to have covered this part of Sleat; but the position of the rocks which I am about to describe makes it probable that this continuation did formerly exist. The denudation of the West of Scotland since early Tertiary time has been so stupendous that I am prepared for almost any seemingly incredible evidence of its effects. There cannot be any doubt, however, that the rocks of which I now speak belong to the great platform of intrusive sheets, and that they were injected under a pile of Secondary strata, if not also of Tertiary basalts, which has here been entirely removed.

In his map of Skye Macculloch showed a small outlier of 'trap' on the western side of the promontory of Sleat. The locality was visited by Prof. Judd, who called the rock a 'phonolite.'[1] During an excursion last year with my colleague Mr. C. T. Clough, I was able to examine the place and to obtain the facts which I now describe.

At Rudh' an Iasgaich, about 2 miles from the Point of Sleat, a small outlier of conglomerate lies on the edges of the Torridon

[1] Quart. Journ. Geol. Soc. vol. xxxiv. (1878) p. 692.

Sandstone. This deposit has been correctly identified by Prof. Judd with the similar strata which in Skye and elsewhere on the west coast of Scotland underlie the Liassic series. It is here about 10 or 12 feet thick, reddish and yellowish in colour, and distinctly calcareous. Its component pebbles consist largely of Cambrian (Durness) limestone, quartzite, and Torridon Sandstone—rocks which all occur *in situ* in Sleat. It may be compared with the limestone-conglomerates of Strath, and those which underlie the Lias at Hoast on Loch Eishort.[1] That here, as elsewhere in this region, the basement-conglomerate was followed by the rest of the Lias and Oolites may be inferred with some confidence from the copious development of the Jurassic Series a few miles off, both to north and south. But the whole of this overlying succession of formations has here been swept away, and, but for the protection afforded by the eruptive rocks of Rudh' an Iasgaich, the conglomerate would likewise have disappeared.

Above the conglomeratic band lies a sheet of intrusive rock, which in one place has apparently cut it out, so as to rest directly upon the Torridon Sandstone (*a* in fig. 23, p. 380). The decay of the softer detrital rock underneath has caused the sill to break off in slices, which have left behind them a bold mural escarpment.

The rock of this sill (*b b*) is a rather coarsely crystalline porphyritic olivine-dolerite, which towards the north attains a thickness of about 70 feet. It exhibits the usual prismatic jointing, though less perfectly than some of the Trotternish sills already referred to. Besides these vertical joints, it is also traversed by a system of horizontal divisional planes which, though somewhat irregular in their course, run, in a general sense, parallel to the upper and under surfaces of the sill.

It seems to have been along this transverse series of joints that a second sill (*c*), 5 or 6 feet thick, has been injected. The material of this younger intrusion is a black, finely crystalline dolerite or basalt, with rudely prismatic jointing. Its most striking feature, besides its regularity of position and persistency for several hundred yards as a platform along the shore, is the basalt-glass which marks both its under and upper surfaces of contact, and which is here developed upon a scale the equal of which I have not met with among the Tertiary sills of this country.

The selvage of glass appears as a black tar-like layer, varying from a mere film to 2 or 3 inches in thickness. It is found not only on the upper and under surfaces, but descends along abrupt step-like interruptions of the upper surface, a foot or more in height, as if the sill had been broken by a series of subsidences. The apparent fracture, however, is probably due to the irregularities of the passage forced for itself by the molten rock, as it passed from one line of horizontal joint to another through the heart of the older sheet.

The exposed surface of black glass on the top of the younger sill

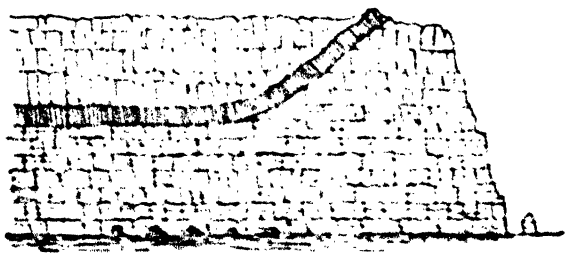
[1] *Op. cit.* vol. xxv. (1869) p. 9; vol. xliv (1888) p. 71.

exhibits long parallel lines, probably marking flow-structure, which are made conspicuous by a pale yellow, ferruginous, weathered crust. Portions of the larger intrusive sheet have been broken off and involved in the later rock. The observer cannot fail to be impressed by the prodigious force with which the sills were injected, when he sees here that a thick sheet of solid dolerite has been actually

Fig. 23.—*Section of dolerite-sill cut by another sill, both being traversed by dykes, Rudh' an Iasgaich, western side of Sleat, Skye.*

split open along the middle. The younger sill disappears to the north, and is not found in the cliff of Rudha Chàrn nan Cearc, where the thick sill, lying once more on the band of conglomerate, forms a fine escarpment above the shore. Dykes of fine-grained basalt with compact chilled margins rise through both sills, together with veins which pursue a wavy upward path like strips of black ribbon.

Fig. 24.—*Sill traversing bedded basalts, cliffs of Stromö, at the entrance of the Vaagofjord.*



[The caves and notches shown at the bottom of the precipice mark the position of the vents represented in Pl. XV. and figs. 8, 9, & 10.]

In the Faroe Islands the actual base of the volcanic series* is nowhere visible. Hence, the great lower platform of intrusive sheets being there concealed, this feature of the basalt-plateaux is less conspicuous than it is in the Inner Hebrides. A number of

sills, however, have been noticed by previous observers,[1] and I have seen others on the sides of Stromö, Kalsö, Kunö, and other islands.

The most remarkable sill in the Faroe Islands is probably that which forms so prominent an object on the western cliffs of Stromo, at the entrance into the Vaagofjord (figs. 24, 25). It is prismatic in structure, and where it runs along the face of the cliffs, parallel to the bedded basalts among which it has been intruded, presents the familiar characters of such sheets. It runs along the face of the precipice which rises above the row of volcanic vents already described. But it there begins to ascend the cliffs obliquely across the basalts, until it reaches the crest of the great wall of volcanic rock at a height of probably about 1000 feet above the waves. From the crest of the precipice the upward course of this sill is continued into the interior of the island. It pursues its way as a line of bold crag along the ridges of the plateau, gradually ascending till it forms the summit of one of the most prominent hills in the district.

Some further idea of the enormous energy with which the sills were injected may be formed from this example, where the eruptive materials followed neither the line of bedding nor a vertical fissure, but took an oblique course through the plateau-basalts for a vertical distance of probably more than 1500 feet.

In Skye a series of remarkable compound sills occurs where a central sheet of acid rock is overlain and underlain by a layer of basic material. I have already described some examples of this structure, and will cite some others in a later part of this paper.

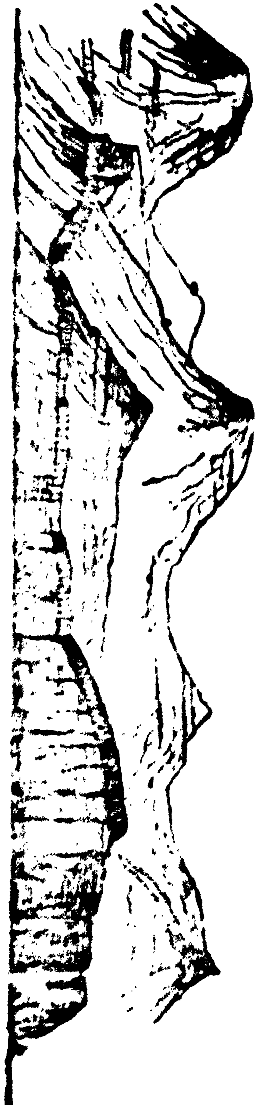


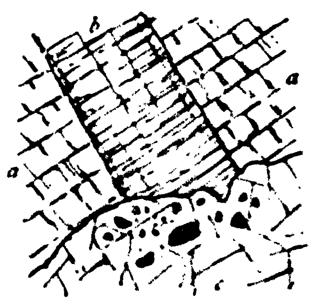
Fig. 25.—View of the same sill, seen from the channel opposite the island of Koltur.

[1] See in particular the description by Trevelyan and Allan, and references by Prof. James Geikie and Mr Lomas already cited.

V. The Dykes.

I have little to add to the full description already given by me of the system of dykes which forms so important a feature in the volcanic history of Tertiary time throughout the North-west of Europe. It is difficult to establish any criterion of the relative dates of protrusion of the dykes; but the important fact announced by me so far back as 1857, that some are older and some later than the great acid bosses of the Inner Hebrides, has been fully confirmed by more recent research all over the region. So far as may be inferred from the geology of the Red Hills of Skye and their surroundings, the vast majority of the dykes belong to a time anterior to the uprise of the bosses of granophyre. As an example of the way in which these bosses truncate the dykes, I may cite here a fresh illustration from the granophyre of Ben an Dubhaich, near Torrin in Skye. The Cambrian limestones of that part of Strath are traversed by numerous dykes which stop short at the edge of the acid rock. As the actual lines of junction are not always visible, it might be contended that the dykes are not necessarily older than the granophyre, but may actually be younger, their sudden termination at the edge of the acid boss being due to their inability to traverse that rock. That this explanation is untenable is readily proved by such sections as that given in fig. 26, where a basic dyke 9 or 10 feet broad running through the Cambrian limestone of Torrin is abruptly cut off by the edge of the great granophyre boss of Ben an Dubhaich. Not only is the dyke sharply truncated, but numerous pieces of it, from 1 to more than 12 inches in length, are enclosed in the granophyre.

Fig. 26.—*Ground-plan of basic dyke (b) in Cambrian limestone (a) truncated by granophyre (c) which encloses large blocks of the dyke. Torrin, Skye.*



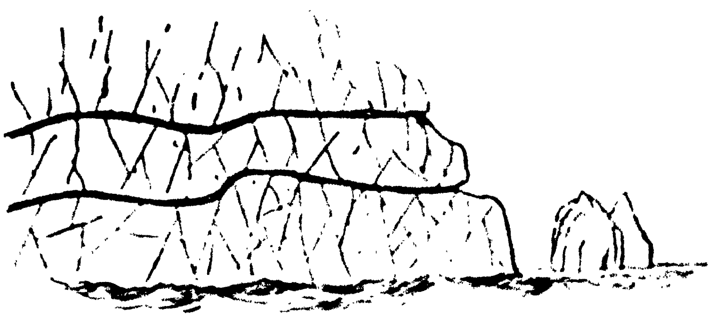
Mr. Harker informs me that, while carrying on the Geological Survey of the district of Strath (Skye), he has obtained data from which it may be possible to determine certain broad distinctions between dykes older and those newer than the intrusion of the granophyres. If these distinctions are found to hold good, they may eventually be applicable to the elucidation of the relative ages of dykes even at a distance from the granophyre, where nothing but petrographical characters are available as a guide.

Numerous basic dykes traverse the gabbros and granophyre of St. Kilda. Those in the former group of rocks are more abundant than those in the latter—a circumstance which is exactly paralleled among the basic and acid bosses of Skye. It is not improbable

that in this remote island a similar difference in age and in petrographical character may be made out between two series of dykes, one older and the other younger than the granophyre.

The pale colour of the precipices in which the St. Kilda granophyre plunges into the sea gives marked prominence to the dark ribbon-like streaks which mark the course of the basalt-dykes through that rock. Moreover, the greater liability of the material of the dykes to decay causes them to weather into long lines of notch or recess. Four or five such dykes follow each other in nearly parallel bands, which slant upward from the sea-level on the eastern face of the hill known as Conacher to a height of several hundred feet (fig. 27).[1]

Fig. 27.—*Basalt-veins traversing granophyre. St. Kilda.*



Dykes abound in the Faroe Islands, where they cut the basalt-plateau in the same way as they do that of the Inner Hebrides. On the whole, however, they do not play, in these northern isles, the important part which they take in the geology and scenery of the West of Scotland. I have not had sufficient opportunity to ascertain whether there is a general direction or system among the Faroe dykes. In the fjords north of Thorshaven, and again along the western side of Stromo, many of them show an east-and-west strike or one from E.N.E. to W.S.W.

Numerous examples of compound dykes, where a central band of granophyre or sphærulitic felsite is flanked on each side by one of basic material, have recently been met with in Skye by Messrs. Clough and Harker in the course of the geological survey of that island. They will be further noticed in the VIIth section of this paper.

[1] This relation of the later dykes to the granophyre was observed here by Macculloch, 'Description of the Western Islands,' vol. ii. (1819) p. 55.

VI. The Intrusive Gabbros.

Some of my more recent observations among the gabbros of Skye have already been communicated to the Society.[1] In conjunction with my colleague Mr. Teall I have described a remarkable banded structure traceable in these rocks, wherein the component minerals have crystallized along different layers in such a manner as to present a singular resemblance to the arrangement characteristic of many Archæan gneisses. Further investigation last summer has shown me that this banding is extensively developed in the Cuillin Hills. The mountains that surround the head of Loch Scavaig and sweep round Loch Coruisk up to the great crests of Sgùrr na Banachdich everywhere display on their bare black crags a distinct bedded structure.

On the eastern side of Loch Scavaig the rock presents a rudely-banded character, the bands or beds being piled over each other from the sea-level up to the summits of the rugged precipices, and dipping into the hill at angles of 25° to 35°. Abundant dykes and veins of various basic, intermediate, and acid rocks cut this structure. The individual layers here, as at Druim an Eidhne,[2] are sometimes wavy and puckered.

Even from a distance the alternating lighter and darker beds can readily be seen, so that the banded structure, with the variations in its inclination, may be followed from hill to hill. The regularity of the arrangement, however, is often less pronounced on closer inspection. While the gabbro is rudely disposed in thick beds, indicative of different intrusive sheets or sills, with which the banding is generally parallel, considerable irregularities may be observed in the arrangement of the structure of individual sheets. These sheets may be parallel to each other, and yet, while in some the banding is tolerably regular in the direction of the planes of the sheets, in others it is much twisted or inclined at various angles.

On the western side of the Coruisk river the banding is vertical; southward from that stream it inclines slightly towards the south, but soon again becomes vertical, and continues conspicuously so at the junction of the gabbro with the Torridon Sandstones and the plateau-basalts on the western side of Loch Scavaig.

In the great corries and ridges of the Cuillin Hills traces of bedding are generally to be recognized, with later sills injected at different horizons and in different directions. Instead of being one great eruptive boss, the gabbro of this district is in reality an exceedingly complicated network of sills, veins, and dykes. While the general inclination of the bedding sometimes continues uniform in direction and amount from one ridge to another, it is apt to change rapidly, as if the complex assemblage of intruded masses had been disrupted and had subsided in different directions.

The gabbro overlies the bedded basalts of the plateau all the way from Glen Brittle to the western side of Loch Scavaig. It then

[1] Quart. Journ. Geol. Soc. vol. l. (1894) pp. 216, 645.
[2] Op. cit. p. 648, and pl. xxvi.

descends abruptly across these basalts and also across the Torridon Sandstone, on which they unconformably rest. These two groups of rocks are not only truncated by the gabbro, but are traversed by the intricate system of sills, dykes, and veins already referred to.

Where it abuts against the sandstones and basalts, the gabbro is arranged in vertical bands of different mineral composition and texture. Much of it is remarkably coarse, some bands displaying pyroxene-crystals more than an inch in length. There is no fine-grained selvage here indicative of more rapid cooling. So coarse, indeed, is the rock close up against the sandstone that the junction-line can hardly be supposed to be the normal contact of the intrusive rock. This inference is confirmed by the existence of a singular kind of breccia between the gabbro and the sandstones. It is a tumultuous mass of fragments of coarse and fine gabbro, Torridon Sandstone and Shale, and plateau-basalts, imbedded in a pale crystalline matrix of fine granular granophyre. Veins from this acid intrusion run off into the gabbro on the one side as well as into the Torridon Sandstone on the other. It would seem that this junction-line has been one of great movement, that the gabbro-sheets have subsided against a fault-wall of plateau-basalt and Torridon Sandstone, and that subsequently an intrusion of finely granular granophyre has come up the fissure, involving in its ascent fragments of all the materials around.

The rocks for a considerable distance to the south of the gabbro are intensely altered. The Torridon Sandstone has been so indurated as to pass into a bleached white quartzite, while the shales interstratified with it have been converted into a kind of porcellanite.

But the most interesting alterations are those to be observed in the plateau-basalts which, at a height of about 300 feet above the sea, are to be seen in nearly horizontal sheets that lie immediately on the upturned edges of the Torridon Sandstone. These lavas have suffered great metamorphism: their alternations of amygdaloidal and more compact sheets can still be recognized, though their enclosed amygdules have in places been almost effaced. They show the dull, indurated, splintery character, with the white weathered crust, which I formerly described as distinctive of this type of contact-metamorphism, and are traversed by numerous sills and veins of gabbro. No large mass of granophyre appears here at the surface. We can hardly be mistaken in looking upon this alteration as due either to the influence of the main body of the gabbro, or perhaps more probably to the abundant acid sills, dykes, and veins, possibly to both causes combined. It must be admitted that there may be a considerable body of granophyre underneath the locality, the surface-dykes and veins being indications of its vicinity.

In my former memoir I dwelt upon the remarkable alteration of the plateau-basalts as they approach the large masses of gabbro or granophyre.[1] During the summer of 1895 Mr. Harker, in the

[1] Trans. Roy. Soc. Edin. vol. xxxv (1888) p. 167. Prof. Judd has referred the alteration of the rocks to solfataric action (Quart. Journ. Geol. Soc. vol. xlvi, 1890, p. 341). I have been unable to detect any evidence of such action. The alteration is always intimately connected with the presence of intrusive masses,

progress of his mapping in the Strath district of Skye, had occasion to go over a number of the localities (Creaghan Dubha, etc.) cited by me, and, while corroborating my general conclusions regarding them, has been able to obtain much fresh evidence regarding the nature and extent of the metamorphism which the bedded basalts have undergone. His results will appear in due time, when the survey of Skye is further advanced. I have submitted to him some slices cut from typical examples of the altered plateau-basalts as they approach the gabbro of Loch Scavaig, and he has supplied me with the subjoined report regarding them:—

'In hand-specimens the bedded basalts from the neighbourhood of the gabbro of Loch Scavaig [6613–6618] do not appear very different from the normal basalts of this region. The most conspicuous secondary mineral is yellowish-green epidote in patches, and especially in the amygdules.

'The texture of the rocks varies, and the slices show that the microstructure also varies, the augite occurring sometimes in small ophitic plates, sometimes in small rounded granules. The chief secondary change in the body of the rock is shown by the augite, which is seen in various stages of conversion to greenish fibrous hornblende. Some round patches seem also to consist mainly of the latter mineral, and are probably pseudomorphs after olivine. Here the little fibres are confusedly matted together, without the parallelism proper to uralite derived from augite. No fresh olivine has been observed. The felspar and magnetite of the basalts show little or no sign of metamorphic processes, unless a rather unusual degree of clearness in the felspar-crystals is to be regarded in that light.

'The contents of the metamorphosed amygdules are not always the same. Epidote is usually present in some abundance, and in well-shaped crystals. It has a pale citron tint in the slices, with marked pleochroism; but a given crystal is not always uniform in its optical characters. Frequently the interior is pale, and has a quite low birefringence: this is probably to be regarded as an intergrowth of zoisite in the epidote, and there are a few distinct crystals of zoisite seen in some places.

'In the slide which best exhibits these features [6613] the crystals of epidote are in part enwrapped and enclosed by what are doubtless zeolitic minerals. At least two of these are to be distinguished. One, very nearly isotropic, and with a pale-brownish tint, is probably analcime. Associated with this is a colourless mineral with partial radiate arrangement and with twin-lamellation: the birefringence is somewhat higher than that of quartz, and the

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and it affects indifferently any part of the basalt-plateaux which may chance to lie next to these masses. The bedded lavas can be traced step by step from their usual unaltered condition in the plateaux to their metamorphosed state next to the eruptive rocks. The nature or degree of the metamorphism has doubtless somewhat varied with the composition and structure of the rocks affected, and with the character and mass of the eruptive material; but it is certainly not confined to the older parts of the plateaux nor to any supposed pre-basaltic group of andesites.

γ-axis of optic elasticity makes a small angle with the twin-line. These characters agree with those of epistilbite. In other parts of the same large amygdule the epidote-crystals are imbedded in what seems to be a felspar. This latter mineral is rather obscure, and twin-lamellation is rarely to be detected; but it seems highly probable that felspar has here been developed by metamorphic agency at the expense of zeolites which once occupied the amygdule. I have observed undoubted examples of this in metamorphosed basalts from other parts of Skye, *e. g.* from Creagan Dubha, near the granophyre-mass of Beinn Dearg.[1] The felspar occurs there in the same fashion, and in the same relation to epidote [2700, 2701]. In the specimens now described the chief minerals in the metamorphosed amygdules are those already named: others occur more sparingly, associated with them. In some cases there is a grass-green, strongly pleochroic, actinolitic hornblende, accompanied by a little iron pyrites [6615].

'Epidote and various hornblendic and augitic minerals are characteristic products in the metamorphism of amygdaloidal basalts in other regions: felspar with this mode of occurrence I have not seen except in Skye, where it seems to connect itself naturally with the abundance of zeolites in the amygdules of the non-metamorphosed lavas. It is to be observed that in these basalts from Loch Scavaig the alteration is shown especially in the amygdules, the body of the rock not being greatly affected: this indicates a not very advanced stage of metamorphism. The production of uralitic hornblende, rather than brown mica, from the augite and its decomposition-products seems to be characteristic of the metamorphism of basaltic as distinguished from andesitic rocks, and is well illustrated by comparison of the two sets of lavas near the Shap Granite.'[2]

A re-examination of parts of the gabbro mountains of Rum has shown me that, though in a less marked degree than in Skye, the same banded structure may be detected in the thick beds or sills of which these eminences are composed. The remarkably schist-like bed of troctolite formerly described by me[3] lies between more massive sheets that show a much ruder parallel structure. The whole mountain of Allival overlying this troctolite is built up of successive parallel sheets of gabbro, among which banding is of frequent occurrence, the layers varying from less than an inch to a foot or more in breadth, and lying parallel to each other and to the upper and under surfaces of the sheets in which they occur. An occasional example of curvature in the banding may be observed.

Compared with the gabbros of the Cuillin Hills, those of Rum display a similar but less definite aggregation of their component minerals in definite layers or bands. In particular, the pyroxene and olivine, either separately or together, are crowded along particular bands of darker hue, while the paler bands between them are composed chiefly of felspar. The crystals or crystalline kernels are

[1] Compare Trans. Roy. Soc. Edinb. vol. xxxv. (1888) p. 166.
[2] Quart. Journ. Geol. Soc. vol. xlix. (1893) p. 361.
[3] Trans. Roy. Soc. Edinb. vol. xxxv. (1888) p. 123; Quart. Journ. Geol. Soc. vol. l (1894) p. 649.

sometimes an inch in diameter, so that when closely grouped along particular layers they give rise to strikingly coarse-grained varieties of rock. Magnetite, on the whole, is rather less conspicuous than in the Cuillin gabbro; at least, it is not so prominently aggregated in special layers.

So rude is the parallel structure in these rocks of Rum that, although quite recognizable on a weathered surface where the constituent minerals are revealed by the way in which they respectively decay, it is often hardly to be detected on a freshly-broken exposure.

The western and more rugged part of the island of St. Kilda[1] is built up of various gabbros, dolerites, and basalts, traversed by dykes and veins of similar material. The gabbros include rocks of coarse, medium, and fine grain, like those of Skye, which lie in sheets or sills, but also apparently in large irregularly-shaped masses. In one or two places I noticed a faint banding, but my opportunities of studying these rocks were cut short by a change of weather which necessitated an abrupt departure, there being no safe anchorage at the island. I sailed round the coast, however, near enough to form a good idea of the general structure of the rock. Like the corresponding masses of the Cuillin Hills, the St. Kilda gabbro arrests attention by its singular blackness of tone, varied by its yellow coating of lichens and its grey crust of weathering, while its occasional slopes of débris are covered with a thick bright-green carpet of turf formed of matted sea-pink.

While the gabbros of St. Kilda are not a mere uniform boss, but rather a series of sills and irregular masses which have been successively injected into each other, they have subsequently been cut through by the basalt-dykes and veins already noticed. These, which are sometimes as abundant as in the gabbro of the Cuillin Hills, traverse the rock at all angles, and, as they generally weather faster than it does, they give rise to deep clefts which ascend the precipices, occasioning sea-caves below and sharp notches on the crests above.

These scenic features, so indicative of the geological structure that causes them, are specially well seen on the western face of the Dune or south-western promontory of the island, and likewise in the strangely rifted precipices to the north. They are, however, still more impressively displayed around the naked walls of the neighbouring islet of Borrera (1000 feet high), which consists entirely of gabbro pierced with dykes, and in its marvellous combination of spiry ridges, deep straight gullies, and splintered crests, reminds one at every turn of the scenery of Blaven and the Cuillin Hills.

Nowhere in St. Kilda or its dependent islets can any certain trace be obtained of a rock more ancient than the gabbros. So great has been the denudation that the eruptive core of this volcanic district has been reduced merely to a few scattered islets. If, as is probable, this core was once surrounded and covered by a plateau of basalt, no fragment of such a plateau remains, unless we may be

[1] For references to published information on the geology of this island see pp. 389, 390.

allowed to recognise it among some of the basalt-sheets included among the gabbros.

Like their counterparts in the Inner Hebrides, these rocks have not only been traversed by basic dykes, but have been invaded by a large mass of granophyre. The junction of the acid and basic materials repeats the evidence already cited from Mull, Rum, and Skye, and proves beyond all question that the acid rock is the younger of the two. The characters of this junction will be given in the next section of this paper.

It is interesting to observe that, while in St. Kilda no relic of any basaltic plateau has been preserved, in the Faroe Islands, on the other hand, no sign has been revealed by denudation that the volcanic plateau of that region has any eruptive core of gabbro or of granophyre. During my cruises round these islands and through their channels, I was ever on the outlook for any difference in topography that might indicate the presence of some eruptive boss like the gabbro- and granophyre-masses of the Inner Hebrides. But nothing of that nature could be discerned. Everywhere the long level lines of the bedded basalts mounted up to the crests of the ridges and the tops of the highest peaks. Though I cannot assert that no intrusions of gabbro or of granophyre exist among the Faroe Islands, I feel confident that any such masses which may occur must be of quite insignificant dimensions, and do not make the important feature in geology and topography which they do among the Inner Hebrides.

VII. The Granophyre Intrusions.

Having recently brought the subject of the Tertiary granophyres before the Society,[1] I shall content myself in the present paper with an account of some additional examples of their occurrence and of their relations to the other members of the volcanic series.

St. Kilda supplies fresh evidence of much interest in this part of the volcanic history. The visitor, in approaching the island, especially from the southern or northern side, will notice the same two strongly contrasted topographical features as those that are so well exhibited in the centre of Skye. Along the western side rise the black rugged crags of gabbro. The eastern precipices are pale in colour, and are capped by rounded or conical hills, which towards the interior send down long screes of grey or russet-coloured debris. Their forms are so like those of the Red Hills of Skye that the geologist recognizes their true nature and respective limits, even before setting foot on them.

To Macculloch we are indebted for the first good description of the rocks of St. Kilda.[2] He clearly identified the pale rock of the eastern half of the island with the 'syenite' or granophyre of Skye, and he further remarked that it presented much resemblance to some parts of the granite of Arran. He observed 'fragments of trap penetrated by veins of syenite,' but he did not see these

[1] Quart. Journ. Geol. Soc. vol. l (1894) pp. 212-229.

[2] 'Description of the Western Islands,' vol. ii. (1819) p. 54.

rocks in place, and, in spite of their apparent testimony to the posteriority of the acid intrusions, he was inclined to believe that the veins were not real veins, but that the 'trap' and 'syenite' had a common origin and would be found to pass into each other, as he thought also occurred in Mull and Rum. In recent years Mr. Alexander Ross has visited St. Kilda and published an excellent account of its geology.[1] He collected specimens illustrating the varieties of gabbro, dolerite, and basalt, and showing the intrusion of the acid into the basic rocks. He was disposed to believe the 'granite' to be of younger date than the gabbros, but left the question open for further consideration.

The acid rock which forms the eastern side of this island, variously termed 'syenite' and 'granite,' weathers in thick bed-like sheets, divided by transverse joints into large quadrangular blocks, like many granites. On closer inspection it is found to resemble still more precisely the acid rocks of the Inner Hebrides. It possesses the same drusy micropegmatitic structure as the granophyres of Skye, Rum, and Mull. The ferro-magnesian constituents are present in small quantity, hence the pale hue of the stone. The quartz and felspar project in well-terminated crystals into the drusy cavities, which are sometimes further adorned with delicate tufts of clear, crystallized epidote. In many respects the rock resembles the young granites of Arran and the Mourne Mountains.

Mr. Harker's notes on the microscopic structure of this granophyre are as follows:—'The prevailing felspar is orthoclase, often very turbid from secondary products. Even what appear to be distinct crystals are sometimes seen in the slices to be invaded in the margin by quartz in rough micrographic intergrowths, and much of the finer intergrowth occurs as a fringe to the crystals. In this case the felspar of the micropegmatite can often be verified to be in crystalline continuity with the crystal which has served as a nucleus [6624]. Quartz occurs in distinct crystals and grains as well as in the micropegmatite. There is a more granitoid variety of the rock, in which only a very rude approach to micrographic intergrowths is seen [6623]. In both varieties there is but little trace of any ferro-magnesian mineral; the more typical granophyre has what seems to be destroyed augite, while the granitoid rock contains a little deep-brown biotite. Scattered crystal-grains of magnetite occur in both.'

Narrow ribbon-like veins of a finer material, sometimes only an inch in breadth, traverse the ordinary granophyre. Similar veins run

[1] Brit. Assoc. Rep. 1885 (Aberdeen meeting) p. 1040; and a much fuller paper in the Proc. Inverness Field Club, vol. iii (1884) p. 72. In this latter paper a letter from Prof. Judd is quoted, in which he states that the rock supposed to be granite 'is seen under the microscope to be a quite different rock—a quartz-diorite,' p. 78. Some of the specimens from St. Kilda collected by Mr. Ross were exhibited at the meeting of this Society on January 25th, 1893. With regard to these, Prof. Judd, in the course of the discussion on his paper on 'Inclusions of Tertiary Granite in the Gabbro of the Cuillin Hills,' remarked:—'They show a dark rock traversed by veins of a light one, but the dark rock is not a gabbro, and the light rock is not a granite,' Quart. Journ. Geol. Soc. vol. xlix. (1893) p. 198.

through the rock of the Red Hills in Skye: they are sharply defined from the enclosing rock, as if the latter had already solidified before their intrusion.

With regard to the microscopic structure of some thin slices prepared from these veins, Mr. Harker remarks that 'the material of the veins is of a type intermediate between granophyre and microgranite (6622, 6623). The chief bulk is a finely granular aggregate of quartz and felspar, the latter very turbid; but in this aggregate are imbedded numerous patches of micropegmatite, often of perfect and delicate structure. These areas of micropegmatite show some approach to a radiate or rudely spherulitic structure, and, in some cases, are clustered round a crystal of felspar or quartz. Some granules of magnetite and rare flakes of brown biotite are the only other constituents of the rock. Although they must be of somewhat later date, there is evidently nothing in the petrographical characters of these fine-textured veins to separate them widely from the ordinary granophyres of the region.'

These veins may be compared with the spherulitic dyke which traverses the granophyre of Meall Dearg at the head of Glen Sligachan, and which, though undoubtedly somewhat later than the rock that contains it, yet presents the very same structures as are visible at the margin of that rock.[1] The material of this dyke, and of the finer veins of St. Kilda and the Red Hills, probably belongs to a later period of protrusion from a deeper unconsolidated portion of the same acid magma as that which at first supplied the general body of granophyre.

Undoubtedly the most interesting feature in the granophyre of St. Kilda is its junction with the mass of basic rock to the west of it. It requires no close search to find *in situ* the dark rock with acid veins of which Macculloch found scattered fragments. The line of junction between the basic and acid masses runs across the island from the western side of the chief bay to the northern coast, where it is exposed in a line of high cliffs.

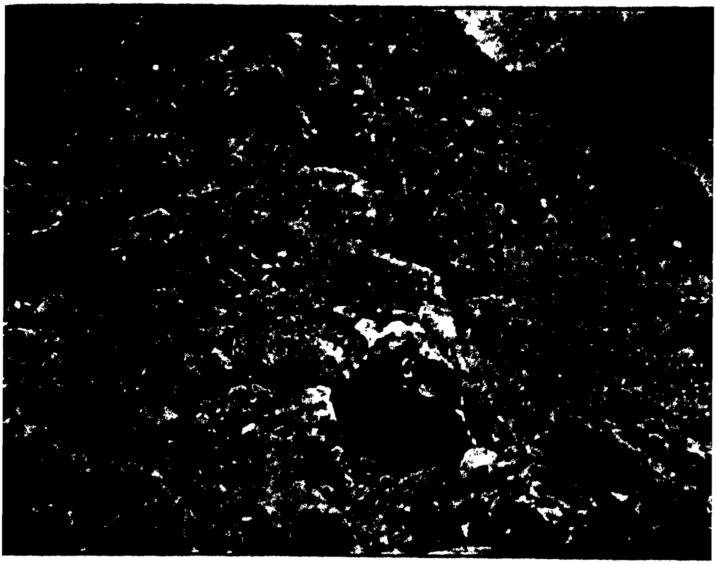
The beach to the west of the landing-place in the bay is strewn with blocks of various dark, finely crystalline basic rocks, traversed by pale veins of granophyre. At the western end of the shingle, the rocks are met with in places forming a line of low cliff and a rugged foreshore. The basic rock consists of various gabbros and basalts of rather fine grain, profusely traversed with veins of white granophyre. Some of these veins are 2 feet or more in breadth, and, when of that size, show the distinctive granular texture and drusy structure of the main part of the acid rock. But from these dimensions they can be traced through every stage of diminution until they become mere threads. When they are only an inch or two broad they assume a finely granular texture, like that of the veins which run through the body of the granophyre.

The amount of injected material in the dark basic rocks is here and there so great as to form a kind of breccia (fig. 28, p. 392), which, from the contrast of tone between its two constituents, makes a conspicuous object on the shore. The enclosed fragments are of

[1] Quart. Journ. Geol. Soc. vol. l. (1894) p. 220.

all sizes from mere grains up to blocks a foot or more in length. They are generally angular, like rock-chips from a quarry. The granophyre here and there assumes a darker or greener tint, as if it had dissolved and absorbed some portion of the older rock.

Fig. 28.—*Pale granophyre injected into dark basalt. St. Kilda.*
[From a photograph by Col. Evans.]



Though closer in grain where it comes in contact with the gabbro, the granophyre never assumes any vitreous or distinctly spherulitic textures along its margin. A series of thin slices prepared from my specimens has been examined for me by Mr. Harker, who has furnished the following notes regarding them:—'The basalt traversed by the granophyre is a fine-textured variety, with small porphyritic felspars. These latter seem to be usually unaltered, retaining the glass-cavities which in some of the crystals are abundant. The groundmass, however, shows minerals of metamorphic origin which must be derived mainly from the original augite. A brown mica is the most conspicuous; but with it are associated some brownish-green hornblende and certain chloritic and perhaps serpentinous substances. It is chiefly near the margin of a fragment of basalt that the mica gives place to these minerals. The basalt still retains plenty of unaltered granules of augite in the central parts of a fragment. It is not certain that the secondary minerals named come exclusively from the augite of the basalt; judging from their form and mode of occurrence I should say that they may in part have replaced olivine or even rhombic pyroxene.

'The acid rock, though styled granophyre above, belongs to a granitoid variety of that group of rocks, and has but little indication of micrographic structures. Compared with the other granophyres from St. Kilda, sliced and examined, these examples show a less acid composition. This is expressed mineralogically in the presence of a somewhat larger proportion of ferro-magnesian minerals and of soda-lime felspar. These features might indeed be matched in many normal granophyres among the Western Isles, but in the present case it can hardly be doubted that they are to be explained, at least in some degree, by the acid magma having taken up a certain amount of material from the basalt. Many of these Tertiary granophyres have undoubtedly been modified by the incorporation of pieces of basalt and gabbro, and a collection made in the Strath district of Skye will furnish examples for future study. Prof. Sollas's description of similar phenomena in the Carlingford district has already proved the importance of this kind of action.[1] In the present instance, both brown mica and hornblende occur plentifully in the granophyre, and especially round the basalt-fragments. This latter point is conclusive as to the derivation of the basic material, and further proves a certain degree of viscosity in the acid magma at the time of its intrusion.'

On the northern side of St. Kilda the junction-line of the granophyre runs up the cliffs, abundant pale veins of the acid material striking off from the main body of the rock and traversing the dark gabbros.

The testimony of the rocks of St. Kilda to the posteriority of the granophyre to the gabbros and basalts is thus clear and emphatic. It entirely confirms my published observations regarding the order of sequence of these rocks in Mull, Rum, and Skye. But the St. Kilda sections display, even more strikingly than can be usually seen in these islands, the intricate network of veins which proceed from the granophyre and the shattered condition of the basic rocks which these veins penetrate.

I have already alluded to the remarkable association of acid and basic material in numerous dykes as well as in some sills in the district of Strath in Skye. I formerly described some examples of this association from that district,[2] and many more have recently been observed and mapped by Mr. Clough and Mr. Harker during the progress of the Geological Survey. The conjunction commonly shows a central and thicker band of granophyre or spherulitic felsite with two thinner parallel bands of some dark intermediate or basic rock. This triple arrangement occurs both in dykes and sills.

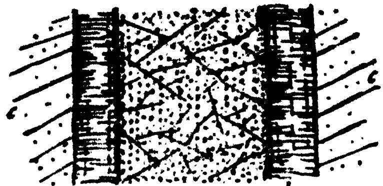
As an illustration of the association of the two kinds of rock in dykes I may cite the example which appears on the southern edge of the Market Stance of Broadford (fig. 29, p. 394). Here the characteristic triple arrangement is typically developed. A central light-coloured band, about 8 to 10 feet broad, consists of a spherulitic granophyre in which the spherulites are crowded together and project from the weathered surface like peas, though they do not here show the curious rod-like aggregation so marked in some other

[1] Trans. Roy. Irish Acad. vol. xxx. (1894) pp. 477-512.
[2] Trans. Roy. Soc. Edinb. vol. xxxv. (1888) p. 174.

dykes. On either side of this acid centre a narrow basalt-dyke intervenes as a wall, next to the Torridon Sandstone which here forms the country-rock.

In this instance, and generally throughout the district, there is nothing to indicate that the different bands of the dyke have any relation to each other as connected uprises of material from the same original magma which was undergoing a process of differentiation beneath the terrestrial crust. On the contrary, the several parts of each dyke are as distinctly marked off from each other as they could have been had they been injected at widely separated intervals of volcanic activity.

Fig. 29.—*Compound dyke. Market Stance, Broadford, Skye.*



a. Granophyre; *b b.* Basalt; *c c.* Torridon sandstone.

The same indication of an independent origin is displayed by the rocks when they form compound sills, with a thick central sheet of acid material overlain and underlain by some more basic rock. I have shown that the posteriority of the acid sill may sometimes be demonstrated by its sending out veins into the darker sill above or below it.[1] But a more striking proof of the independence of the two kinds of rock may be seen at Suishnish Point, in the Isle of Raasay (fig. 30). Here the Pabba Shales of the Lower Lias (*a a*) are surmounted by a sheet of granophyre (*b*), of which the top has been removed by denudation. This rock occupies about 5 square miles in the southern half of the island, where it has recently been mapped by Mr. H. B. Woodward for the Geological Survey. It has been intruded across the Jurassic Series, a large part of its mass coming in irregularly about the top of the thick white sandstones of the Inferior Oolite. But it descends beneath the Secondary rocks altogether, and in some places intervenes between the base of the Infra-Liassic conglomerates and the Torridon Sandstone.

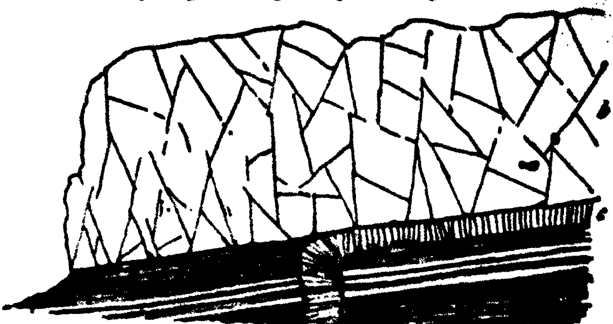
The central portions of this Raasay granophyre possess the ordinary structures of the corresponding rocks in Skye. They show a fine crystalline-granular micropegmatitic base, through which large felspars and quartzes are dispersed. But at the upper and under junctions with the sedimentary rocks beautiful spherulitic structures are developed. This is well seen on the shore near the Point of Suishnish, where, below the Liassic limestones, the top of the granophyre appears, and where its bottom is seen to lie on the Torridon Sandstone.

Where the eruptive rock rests on the Pabba Shales, a basalt-dyke which rises through these strata turns abruptly at the base of the acid rock and then pursues its course to one side as a sill (*c*)

[1] Trans. Roy. Soc. Edinb. vol. xxxv. (1888) p. 174.

between the granophyre and the shales. There can be little doubt that this intrusion is later than the granophyre. We have here a basic sill interposed at the bottom of the acid sheet; but in this case we can connect the sill with the actual fissure up which its molten material was impelled.

Fig. 30.—Section of granophyre-sill resting on Lower Lias shales, with a dyke of basalt passing laterally into a sill.



Some remarkable illustrations of the threefold arrangement of compound sills have recently been observed and mapped by Mr. Harker in the Broadford district, one of great interest occurring on the shore at Irishman's Point in Broadford Bay.

VIII. Modern Volcanic Action in Iceland, as illustrative of the History of the Basalt-plateaux of North-western Europe.

Beyond the Faroe Islands, at the further end of the Wyville-Thomson ridge, which stretches across the bottom of that part of the Atlantic Ocean, another basalt-plateau rises in Iceland, presenting many of the familiar characters of those described in this paper, and probably belonging to the same geological period. The bottom of these Icelandic Tertiary basalts is everywhere concealed under the sea. Yet their visible portion shows them to be probably more than 3000 metres in thickness.

An especial interest belongs to this Icelandic plateau because volcanic action is still vigorous upon it at the present day. A long series of eruptions has taken place there since the Glacial Period. There were likewise abundant pre-glacial eruptions. So far indeed as we know, there is no evidence of any important cessation of the subterranean activity since Tertiary time.[1] The existing volcanic phenomena may with probability be regarded as the survival of those which were so widely manifested over the Icelandic area and the North-west of Europe in the older Tertiary ages. A careful study of them may therefore be expected to throw light on the history of the Tertiary basaltic plateaux; while, on the other hand, the thorough dissection of these plateaux by the denuding agencies

[1] See Johnston-Lavis, Scottish Geogr. Mag. 1896, p. 442.

will not improbably be found to explain some parts of the subterranean mechanism of the Icelandic volcanoes.

In calling attention to some of the more obvious analogies which may be traced between the modern and the ancient volcanoes, I am more particularly indebted to the excellent memoirs of the resident Icelandic geologist Mr. Th. Thoroddsen, who has examined so large a part of the island.[1] The account given by A. Helland of the Laki craters has likewise been of much service to me.[2] Among other recent observers I may cite Dr. Tempest Anderson,[3] who has made himself familiar with extensive tracts of Iceland, and Dr. Johnston-Lavis, who has published the narrative of a journey in company with him.[4]

It is a mistake to suppose that the Icelandic volcanoes are generally built on the plan of such mountains as Vesuvius or Etna. Evidently Mr. Thoroddsen can hardly repress his impatience on finding these two Italian cones cited in almost every handbook of geology as types of modern volcanoes and their operations. The regular volcanic cone composed of alternations of lavas and tuffs hardly occurs in Iceland at all. The fundamental feature in the Icelandic eruptions is the production of fissures which reach the surface and discharge streams of lava from many points.

Two systems of fissures appear to be specially marked, one running from south-west to north-east, the other from south to north.[5] Hekla and Laki belong to the former. The dislocations have often followed the boundaries of the 'horsts' or solid blocks of country which have withstood terrestrial displacement. The vast outbursts of Odadahraun and Myvatn have almost all issued from fissures of that nature.

The violent eruption of 1875 in Askja found its exit at the intersection of two lines of fissure. Many large fissures were opened on the surface in a nearly north-and-south direction, which could be followed for 80 kilometres. Some of them became the theatre of intense volcanic activity.[6]

Many lines of fissure are traceable at the surface as clefts or 'gjas,' that run nearly straight for long distances, with a width of 1 to 3 yards, and of unknown depth.[7] Occasionally a fissure

[1] See in particular his paper on the volcanoes of N.E. Iceland (Bihang till k. Svensk. Vet Akad. Handl. vol. xiv. pt. ii no. 5, 1888) and that on Snaefell and Faxebugt in the south-west of the island (op. cit. vol. xvii. pt. ii. no 2, 1891); also papers in the Dansk. Geografisk. Tidskrift, vols. xii., xiii (1893–95), and in the Verhandl. Gesellsch. Erdkunde zu Berlin, 1894 & 1895.

[2] 'Lakis Kratere og Lavastromme,' Universitetsprogram. Christiania, 1885. See Mr. Thoroddsen's remarks on this paper, Verhandl. Gesellsch. Erdk. Berlin, 1894, p. 289.

[3] Brit. Assoc. Rep. 1894 (Oxford meeting), p. 650.

[4] Johnston-Lavis, Scot. Geogr. Mag. 1895.

[5] In the Snaefell promontory they run nearly east and west, Thoroddsen, Bihang Svensk. Vet. Akad. Handl. vol. xvii. pt. ii. no. 2, p. 91.

[6] Thoroddsen, op. cit. vol. xiv. pt. ii. no. 5, p. 63.

[7] On the various modes of origin of these chasms, see Tempest Anderson, Brit. Assoc. Rep. 1894, p. 650. Mr. Thoroddsen describes a fissure in the south of Iceland running N.E. for 30 kilometres, with a depth of 130 to 200 metres. It has discharged three great lava-streams, covering a total area of 693 square kilometres.

has not been continuously opened to the surface. An interesting example of such intermittent chasms is supplied by the great rent which gave forth the enormous volume of lava in 1783. The mountain of Laki, composed of palagonite-tuff, stands on the line of the dislocation, but has not been entirely ruptured. The fissure has closed up beneath the mountain, a short distance above the bottom of the slope, as is shown by the position of a couple of small craters.[1]

Some fissures have remained mere open chasms without any discharge of volcanic material; others have served as passages for the escape of lava and the ejection of loose slags and cinders.[2]

In some instances, according to Mr. Thoroddsen, lava wells out from the whole length of a fissure without giving rise to the formation of cones, the molten material issuing either from one or from both sides, sometimes flowing out tranquilly, but more usually giving rise to long ramparts of slags and blocks of lava piled up on either side. In the great majority of cases, however, a row of cones is formed along the line of the open fissure. Thus, on the Laki fissure, which runs for about 20 miles in a north-easterly direction, the cones amount to some hundreds in number. Hekla itself appears to have been built up along a main fissure, with parallel subsidiary rents on which rows of cones have been formed.[3]

The cones consist generally of slags, cinders, and blocks of lava. According to Mr. Helland's observations, along the marvellous line of the Laki fissure they are on the whole not quite circular but oblong, their major axis coinciding with the line of the chasm on which they have been piled up. In many places they are exceedingly irregular in form, changes in the direction of outflow of lava or of escape of steam having caused the cones partially to efface each other.

As regards their size, the cones present a wide range. Some of them are only a few yards in diameter, others several hundred yards. Generally they are comparatively low mounds. On the Laki fissure some are only a couple of yards high; the majority are much less than 50 yards in height, and hardly one is as much as 100 yards.[4] And yet these little monticules, as Mr. Helland remarks, represent the pipes from which milliards of cubic metres of lava have issued. While other European volcanoes form conspicuous features in the landscape, the Icelandic volcanoes of the Laki district, from which the vastest floods of lava have issued in modern times, are so low that they might escape notice unless they were actually sought for.[5]

As they have generally arisen along lines of fissure, the cones are for the most part ranged in rows. The hundreds of cones that

[1] A. Helland, 'Lakis Kratere og Lavastrømme,' p. 25.

[2] Mr. Thoroddsen has observed that in the Reykjanes peninsula, in the S.W. of Iceland, by the subsidence of one side of a fissure, a row of four craters has been cut through, leaving their segments perched upon the upper side ('Globus,' vol. lxix. no. 5).

[3] Johnston-Lavis, *op. cit.* p. 457.

[4] Mr. Thoroddsen, however, states that there are about 100 between 20 and 100 metres in height.

[5] A. Helland, *op. cit.* p. 27.

mark the line of the Laki fissure present an extraordinary picture of volcanic energy of this type. In other instances the cones occur in groups, though this distribution may have arisen from the irregular uprise of scattered vents along a series of parallel fissures. Thus to the north-east of Laki a series of old cones, entirely surrounded by the lavas of 1783, lie in groups, the most northerly of which consists of about one hundred exceedingly small craters that have sent out streams of lava towards the north-north-east.[1]

It would appear from Mr. Helland's observations that the same fissure has sometimes been made use of at more than one period of eruption. He describes some old craters on the line of the Laki fissure, which had been active long before the outbreak of 1783.[2]

When the lava issues from fissures it is in such a condition of plasticity that it can be drawn out into threads and spun into ropes. When the slope over which it flows is steep it often splits up into blocks on the surface. Where the ground is flat the lava spreads out uniformly on all sides, forming wide plains as level as a floor. Thus the vast lava-desert of Odadahraun covers a plain 3640 square kilometres in area, or, if the small lava-streams north from Vatnajokull be included, 4300 square kilometres. This vast flood of lava (about 1700 English square miles in extent) would, according to Mr. Thoroddsen, cover Denmark to a depth of 16 feet. The whole of this enormous discharge has been given forth from more than twenty vents situated for the most part on parallel fissures.

Not less striking is the picture of fissure-eruption to be met with at Laki—the scene of the great lava-floods of 1783. 'Conceive now,' says Mr. Helland, 'these hundreds of craters, or, as they are called by the Icelanders, "borge," lying one behind another in a long row; every one of them having sent out two or more streams of lava, now to the one side, now to the other. Understand further that these streams merge into each other, so as to flow wholly round the cones and form fields of lava miles in width, which, like vast frozen floods, flow down to the country districts, and you may form some idea of this remarkable region.'[3]

In the course of time the successive streams of lava poured out upon one of these wide volcanic plains gradually increase the height of the ground, while preserving its generally level aspect. The loose slag-cones of earlier eruptions are effaced or swallowed up, as one lava-stream follows another. Eventually, when, by the operation of running water or by fissure and subsidence, transverse sections are cut through these lava-sheets, the observer can gene-

[1] A. Helland, 'Lakis Kratere og Lavastrømme,' p. 25. [2] *Op. cit.* p. 26.

[3] *Op. cit.* p. 24. Mr. Helland allows an average thickness of 30 metres for the mass of lava which issued in two streams, one 80 kilometres (nearly 50 miles), the other 45 kilometres (about 28 miles) long. He estimates the total volume of lava discharged in the 1783 eruption at 27 milliards of cubic metres, equal to a block 10 kilometres (6 miles 376 yards) long, 5 kilometres (3 miles 186 yards) broad, and 540 metres (1771 feet) high; *op. cit.* p. 31. Mr. Thoroddsen remarks that the older estimates of the volume of lava discharged by this eruption have been greatly exaggerated. He puts the area covered by lava at 565 square kilometres, and the contents at 12⅓ cubic kilometres (Verhandl. Gesellsch. Erdk. Berlin, 1894, p. 298).

rally notice only horizontal beds of lava piled one above another, including the dykes connected with them and intercalated masses of loose slag, that remain as relics of the old craters.

In some places the lava has gradually built up upon its parent fissure an enormous dome, having a gentle inclination in every direction, as may be seen especially in the district between Flodorne Skjalfandafljot and Jökulsà. Most of the large volcanic piles of North Iceland are of this nature. The highest of them are 1209 and 1491 metres high by from 6 to 15 kilometres in diameter. The elliptical crater of the highest of these eminences measures 1100 by 380 metres.[1]

There is still another feature of the Icelandic volcanic regions which may be cited as an interesting parallel to the sequence of eruptive discharges among the Inner Hebrides. While the main mass of the lavas is more or less basic, many of them being true basalts, they have been at different times pierced by intrusions and outflows of much more acid liparites, and even of granophyre. Examples of these rocks of post-glacial age have recently been traced on the ground by Thoroddsen,[2] and their petrographical characters have been studied by Backstrom.[3] The wide distribution of such rocks all over the island, their occurrence in isolated bosses among the more basic lavas, and their remarkable internal structures have been noted by several observers.[4]

It will thus be seen how entirely the modern volcanic eruptions of Iceland agree with the phenomena presented by our Tertiary basalt-plateaux. It is to the Icelandic type of fissure-eruptions, and not to great central composite cones like Vesuvius or Etna, that we must look for the modern analogies that will best serve as commentary and explanation for the latest chapter in the long volcanic history of the British Isles.

IX. The Faults of the Plateaux.

There can be no doubt that considerable alterations of level have taken place over the volcanic areas of North-western Europe since the eruptions that produced the basalt-plateaux. The mere fact that in many places the lower members of these terrestrial lavas have been submerged under the sea may be taken to prove a subsidence there since older Tertiary time. Along the western coast of Skye this depression is well shown by the almost entire concealment of the bottom of the plateau under the Atlantic. In the Faroe Isles the subsidence has advanced still further, for not a trace of the

[1] Thoroddsen, Bihang till Svensk Vet. Akad. Handl. vol. xiv. pt. ii. no. 5, pp. 19, 23.

[2] Geol. Fören. Stockholm Förhandl. vol. xiii. (1891) p. 609. Bihang Svensk. Vet. Akad. Handl. vol. xvii. (1891) pt. ii. p. 21; Dansk Geogr. Tidskr. vol. xiii. (1895). He has also found peaks of gabbro and boulders of the same rock brought down from the Vatnajökull. The gabbro rests upon basalt, seems to be associated with granophyres, and is cut by dykes of liparite. It is regarded by Mr. Thoroddsen as belonging to the older Tertiary series and to occur probably in the same way as the gabbro of Mull (op. cit. p. 35).

[3] Geol. Fören. Stockholm Förhandl. vol. xiii. (1891) p. 637.

[4] See in particular C. W. Schmidt, Zeitschr. Deutsch. geol. Gesellsch. vol. xxxvii. (1885) p. 737.

underlying platform on which the basalts rest remains above water. In Iceland, too, the complete submergence of the base of the Tertiary volcanic sheets points to the widespread subsidence of that region.

Another strong argument in favour of considerable subsidence may be derived from a comparison of the submarine topography with that of the tracts above sea-level. It is obvious that the same forms of contour as those which are conspicuous on the land are prolonged under the Atlantic. If we are correct in regarding the valleys as great lines of subaerial erosion, their prolongations as fjords and submarine troughs must be regarded as having had a similar origin. We can thus carry down the surface of erosion several hundred feet lower than the line along which it disappears under the waves.

I know no locality where this kind of reasoning is so impressively enforced upon the mind as the western end of the Scuir of Eigg. The old river-bed and its pitchstone terminate abruptly at the top of a great precipice. Assuredly they must once have continued much farther westward, as well as the sheets of basalt that form the main part of the cliff. Yet the sea in front of this truncated face of rock rapidly deepens to fully 500 feet in some places. Had any such hollow existed in the volcanic period it would have been filled up by the long-continued outflowings of basalt. We can only account for this submarine topography by regarding it as having been carved out, together with the topography of the land, at a time when the level of the latter was at least 500 feet higher than it is now.

The subsidence which is thus indicated along the whole of the North-west of Europe probably varied in amount from one region to another. We seem to have traces of such an inequality in the varying inclinations of different segments of the basalt-plateaux. The angles of inclination are almost always gentle, but they differ so much in direction from island to island, and even among the districts of the same island, as to indicate that certain portions of the volcanic plain sank rather more than other portions.

Thus in the Faroe Islands, where the bare cliffs allow the varying angles of inclination to be easily determined, a general gentle dip of the basalts in a south-easterly direction has been noted by previous observers. This inclination, however, is replaced among the southern islands by an equally gentle dip towards the north-east. The centre of depression would thus seem to lie somewhere about Sandö and Skuö. The highest angle of inclination which I noticed anywhere was at Myggenaes, where the basalts dip E.S.E. at about 15°.

Though I have not observed any features among the basalt-plateaux that can be compared to the remarkable rifts and subsidences of Iceland, it can be shown that these piles of volcanic material have undoubtedly been fractured, and that portions of them have subsided along these lines of dislocation. Careful examination of the basalt-escarpments of the Inner Hebrides discloses the existence of numerous faults which, though generally of small displacement, nevertheless completely break the continuity of all the rocks in a precipice of 700 or 1000 feet in height. Not infre-

quently such dislocations give rise to clefts in the cliffs. Some good illustrations of this feature may be noticed on the northern side of the island of Canna, where the highest part of the precipice has been fissured by a series of dislocations, having a hade towards the west and a throw which may in some cases amount to about 20 or 25 feet. The cumulative effect of this system of faulting, combined with a gentle westerly dip, is to bring down to the sea-level the upper band of conglomerate which farther east lies at the top of the cliff. Again, the basalt-escarpment on the western side of Skye, from Dunvegan Head to Loch Eynort, is traversed by a number of small faults. On the eastern side of Skye and in Raasay a series of faults, some of them having perhaps a throw of several hundred feet, has been mapped by Mr. H. B. Woodward.

The largest dislocation observed by me among the fragments of the basalt-plateaux is that which runs at the back of the Morven outlier, in the west of Argyleshire.[1] It runs from the head of Loch Aline to the mouth of Loch Sunart along the line of valley that contains the salt-water fjord Loch Teacus and the freshwater lakes Loch Durinemast and Loch Arienas. While the Cretaceous deposits and the bottom of their overlying basalts rise but little above the sea-level on the south-western side of this line, they are perched as outliers on hilltops on the north-eastern side, where they rise to 1300 feet above the sea. The amount of vertical displacement here probably exceeds 1000 feet. The fault runs in a north-westerly direction, and has obviously been the guiding influence in the erosion of the broad and deep valley which marks its course at the surface.

To what extent the dislocations that traverse the Tertiary basalts of the Inner Hebrides are to be regarded as comparable to those which in Iceland have been referred to subsidence caused by the tapping and outflow of the lower still liquid parts of lava-sheets must be matter for further enquiry. So far as my own observations have yet gone, the faults do not seem explicable by any mere superficial action of the kind supposed. Where they descend through many hundreds of feet of successive sheets of basalt and dislocate the Secondary rocks underneath, they must obviously have been produced by much more general and deep-seated causes.

It is conceivable that, if these dislocations took place during the volcanic period, they broke up the lava-plains into sections, some of which sank down so as to leave a vertical wall at the surface on one side of the rent, or even to form open 'gjas,' like those of Iceland. But it is noteworthy that the fissures which have been filled with basalt and now appear as dykes, comparatively seldom show any displacement in the relative levels of their two sides. In Iceland, also, the great lava-emitting fissures seem to be in general free from marked displacement of that kind.

The faults in the Inner Hebrides, so far as I have observed, are all normal, and indicate nothing more than gentle subsidence. But among the Faroe Islands I have come upon several instances of reversed faults, which, in spite of the gentle inclinations of the

[1] This fault was noticed by Prof. Judd traversing the cliffs of the Sound of Mull, and is referred to in my memoir already cited.

basalts, probably point to much more vigorous displacement within the terrestrial crust.

On the eastern side of Svinö a fault with a low hade runs from sea-level up to the top of the cliff, a height of several hundred feet. It has a downthrow of a few yards, but is a reversed fault, as will be seen from fig. 31. Another similar instance may be noticed on the north-eastern headland of where, however, on the side, the basalts appear as if they had been driven upward, a portion of them having been pushed up into a low arch (fig. 32).

Fig. 31.—*Reversed fault on the eastern side of Svinö, Faroe Isles.*

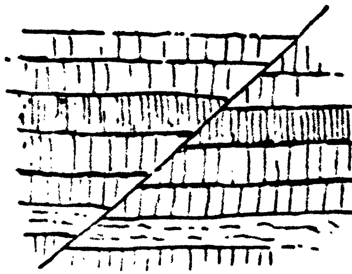
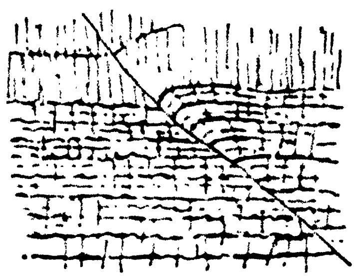


Fig. 32.—*Reversed fault on the N.E. headland of Sandö, Faroe Isles.*



When the Tertiary basalt-plateaux come to be worked out in detail, many examples of dislocation will doubtless be d. We shall then more of the amount and of the terrestrial disturbances which have affected North-western Europe since older Tertiary time. In the meantime evidence enough has been adduced to prepare us for proofs of very considerable recent displacements even among regions of crystalline schists like that which has been disrupted by the Morven fault above alluded to. While the study of the Tertiary volcanic rocks demonstrates the vast general denudation of the country since older Tertiary time, the proofs that these rocks have been faulted acquire a special interest in relation to the origin and evolution of the topography of the region.

X. The Effects of Denudation.

Among the more impressive lessons which the basalt-plateaux of North-western Europe teach the geologist, the enormous erosion of the surface of this part of the continental area since older Tertiary time takes a foremost place. He may be ready almost without question to accept the evidence adduced in favour of a vast amount of denudation among such soft and incoherent strata as those of the older Tertiary formations of the South-east of England. But he is hardly prepared for the proofs which meet him among the north-western isles that such thick masses of solid volcanic rocks have been removed during the same geological interval.

To gain some idea of the amount of this waste we must, in the first place, picture to our minds the extent of ground over which the lavas were poured, and the depth to which they were piled upon it. Whether the now isolated basalt-plateaux of Britain were once united into a continuous plain of lava may never be ascertainable. It is quite certain that every one of these plateaux was formerly much more extensive than it is now, for each of them presents as its terminal edge a line of wall formed by the truncated ends of horizontal basalt-sheets. And there seems no improbability in the assumption that the whole of the great hollow from the centre of Antrim up to the Minch was flooded with lavas which flowed from many vents between the hills of ancient crystalline rocks forming the line of the Outer Hebrides on the west, and those of the mainland of Scotland on the east.

The depth to which some parts of this long hollow were overflowed with lava exceeded 3000 feet. The original inequalities of surface were buried under the volcanic materials which were spread out in a vast plain or series of plains, like those that have been deluged by modern eruptions in Iceland. Owing, however, to a general but unequal movement of subsidence, the lava-fields sank down here and there to, perhaps, an extent of several hundred feet, so that the old land-surface on which they began to be poured out now lies in those places below the level of the sea.

I have shown that even during the volcanic period, while the lavas were still flowing from time to time, erosion was in active progress over the surface of the volcanic plain. The buried river-channel of the Scuir of Eigg, and the records of water-action described in the present paper, prove that rivers descending from the mountains of the Western Highlands carried the detritus of these uplands for many miles across the lava-fields, swept away the loose material of volcanic cones, and cut channels for themselves out of the black rugged floor of basalt.

The erosion thus early begun has probably been carried on continuously ever since. The present streams may be looked upon as practically the same as those which were flowing in the Tertiary period. There may have been slight changes of level, oscillations both upward and downward in the relative positions of land and sea, and shiftings of the watercourses to one side or other, but there seems no reason to doubt that the existing basalt-plateaux, which were built up as terrestrial areas, have remained land surfaces with little intermission ever since, although their lower portions may have been in large measure submerged.

In the existing valleys, fjords, and sea-straits by which these plateaux have been so deeply and abundantly trenched, we may recognize some of the drainage-lines traced out by the rivers which flowed across the volcanic plains. The results achieved by this prolonged denudation are of the most stupendous kind. The original lava-floor has been cut down into a fragmentary tableland. Hundreds of feet of solid rock have been removed from its general surface. Outliers of it may be seen scattered over the mountains of Morven, whence they look into the heart of the Highlands. Others cap the hills of Rum, where they face the open Atlantic.

Far away from the main body of the plateau in Skye, a solitary remnant, perched on the highest summit of Raasay, bears eloquent witness that the basaltic tableland once stretched far to the east of its present limits.

Some of the valleys thus excavated out of the volcanic sheets are many miles long, a mile or more wide, and, from crest to bottom, several thousand feet deep. The deep winding sea-lochs of Mull and the west of Skye form striking monuments of this part of the waste.

Yet, impressive as are these proofs of denudation, they are perhaps inferior in this respect to the evidence furnished in the same region by the great cores of gabbro and granophyre. These eruptive masses must once have lain under a thick pile of basalt, for they obviously belong to part of the deeper-seated mechanism of the volcanic vents. Yet of this vast overlying mantle every trace has been stripped off from many of these cores, while in others mere patches of it remain where they were welded to the intrusive bosses by the heat of eruption.

Moreover, the cores of gabbro and granophyre have been intersected by abundant dykes which reach the present surface of the ground, even up to the crests of the mountains. It is certain that the uprise of these thousands of dykes could not have taken place except under cover of a great depth of rock now removed, for otherwise the basalt would have rushed out from the fissures at the foot of the hills and filled up the valleys, instead of rising between the fissure-walls to the summits of the ridges. Not a single vestige of any lava-stream younger than the gabbros and granophyres has yet been discovered. It is quite possible, perhaps even likely, that the post-granophyre dykes did lead to the outflow of lava here and there at the surface. But any proofs of such emission have been utterly destroyed in the extensive degradation which the plateaux have undergone. By this process of reasoning we can demonstrate that valleys in Skye and Mull 3000 feet deep have been excavated out of the Tertiary volcanic series.

Among the Faroe Islands the evidence of erosion is, in some respects, even more striking. I shall never forget the first impression made on my mind when the dense curtain of mist within which I had approached the southern end of the archipelago rapidly cleared away, and the sunlit slopes and precipices of Suderö, the two Dimons, Skuö and Sandö, rose out of a deep blue sea. Each island showed its prolongation of the same long level lines of rock-terrace. The eye at once seized on these rock-features as the dominant element in the geology and the topography, for they revealed at a glance the true structure of the islands, and gave a measure of the amount and irregularity of the erosion of the original basalt-plateau. And this first impression of stupendous degradation only deepened as one advanced farther north into the more mountainous group of islands. Probably nowhere else in Europe is the potency of denudation as a factor in the evolution of topographical features so marvellously and instructively displayed as among the north-eastern members of the Faroe group. The waste might have been as gigantic among amorphous rocks, such as granites and gabbros, or even among schistose masses, like the Lewisian gneiss. But in these materials

the eye cannot detect any datum-line by which to estimate the loss. In the north-eastern part of the Faroe Isles, however, the horizontal bars of bare rock are continued from cliff to cliff across the deep fjords into the adjoining islands. These terraces afford not only a demonstration that vast hollows have been excavated out of one great volcanic plateau, but also a measure of at least the minimum amount of material so removed.

Availing ourselves of these datum-lines, we easily perceive that in many parts of the Faroe Isles the amount of volcanic material left behind, stupendous though it be, is less than the amount which has been removed. Thus the island of Kalsö is merely a long narrow ridge separating two broad valleys which are now occupied by fjords. The material carved out of these valleys would make several islands as large as Kalsö. Again, the lofty precipice of Myling Head, 2200 feet high, built up of bedded basalts from the summit to below sea-level, faces the north-western Atlantic, and the sea rapidly deepens in front of it to the surface of the submarine ridge 200 to 300 feet below. The truncated ends of the vast pile of basalt-sheets which form that loftiest sea-wall of Europe bear testimony to the colossal denudation which has swept away all of the volcanic plateau that once extended farther towards the west.

Nevertheless, enormous as has been the waste of this plateau of the Faroe Islands, we may still trace some of its terrestrial features that date back probably to the volcanic period. Even more distinctly than among the Western Isles of Scotland, we may recognize the position of the original valleys and trace some of the main drainage-lines of the area when it formed a wide and continuous tract of land.

A line of watershed can be followed in a south-westerly direction from the eastern side of Videro, across Boro to the centre of Ostero, and thence by the Sund across Stromo and Vango. From this line the fjords and valleys diverge towards the north-west and south-east. There cannot be any doubt that on the whole this line corresponds with the general trend of the water-parting at the time when the Tertiary streams were flowing over the still continuous volcanic plain. Considerable depression of the whole region has since then sent the sea up the lower and wider valleys, converting them into fjords, and isolating their intervening ridges into islands.

The topography of the Faroe Islands seems to me eminently deserving of careful study in the light of its geological origin. There is assuredly no other region in Europe where the interesting problems presented by this subject could be studied so easily, where the geological structure is throughout so simple, where the combined influences of the atmosphere and of the sea could be so admirably worked out and distinguished, and where the imagination, kindled to enthusiasm by the contemplation of noble scenery, could be so constantly and imperiously controlled by the accurate observation of ascertainable fact.

Discussion.

The President, after complimenting the Author on the clearness of the exposition of his views, said that from his descriptions we not only obtain a view of these old volcanic vents and lava-flows, but